Hinman and West

Tests of Different Coals
In an Arco Residence-
Heating Boiler (Steam)

Mechanical Engineering
B. S.
1907

UNIVERSITY
OF
ILL. LIBRARY

UNIVERSITY OF ILLINOIS
LIBRARY

Class 1907
Book H59
Volume

Je 07-10M

TESTS OF DIFFERENT COALS IN AN ARCO RESIDENCE-HEATING BOILER (STEAM)

BY

John Harmon Hinman
Porter Royal West

THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE
IN MECHANICAL ENGINEERING

IN THE
COLLEGE OF ENGINEERING
OF THE
UNIVERSITY OF ILLINOIS
PRESENTED JUNE, 1907

1907
H59

UNIVERSITY OF ILLINOIS

June 1, 1907

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

JOHN HARMON HINMAN and PORTER ROYAL WEST

ENTITLED TESTS OF DIFFERENT COALS IN AN ARCO RESIDENCE HEATING BOILER (STEAM)

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Mechanical Engineering

L. P. Breckenridge.

HEAD OF DEPARTMENT OF Mechanical Engineering

103760

UIUC
Library

TESTS OF DIFFERENT COALS
IN AN
ARCO RESIDENCE HEATING BOILER (STEAM)

Order of Presentation.

Preliminary Remarks.

Purpose of Tests.

Description of Apparatus.

Calibration of Apparatus.

Manner of Conducting Tests.

Log Sheets.

Results of Tests.

Calculations.

Conclusions.

Digitized by the Internet Archive
in 2016

https://archive.org/details/testsofdifferent00hinm

Preliminary Remarks.

The Engineering Experiment Station of the University of Illinois is planing to run an extensive series of coal tests in residence heating boilers in order to determine the relative value of and the most economical method of firing the various kinds of coal used in the State of Illinois for house heating purposes.

This thesis, presented for the degree of Bachelor of Science in Mechanical Engineering, consists of a description of the apparatus used together with a detailed account and report of the results of a series of such tests.

This series of tests, eight in number, was conducted in an Arco Steam Heating Boiler, located in the Mechanical Engineering Laboratory of the University of Illinois, and was preliminary to the more extensive series contemplated by the Engineering Experiment Station.

Purpose of Test.

The object of these tests was to determine the relative value of four different coals for use in a residence heating boiler.

Description of Apparatus:

Boiler:- The Arco steam boiler used in these tests was made by The American Radiator Company. Its description and leading dimensions are as follows:-

Catalogue number	1-28-S
Serial number	5866
Rated capacity in sq.ft.of direct radiation	800
Height over all	5'-10-1/4"
Height of water line	4'-8"
Floor space	12 sq.ft.
Size of fire door	9-5/8"x18"
Height of fire door above grate	14"
Area of grate (circular)	4 sq.ft.
Fuel capacity to center of fire door	200 lbs.
Height of furnace	22-1/2"
Approximate width of air space in grate	3/8"
Ratio of air space to entire grate surface	0.5
Least flue area in boiler	0.47 sq.ft.
Water heating surface in direct contact with flames, or fire pot surface,	18.8 sq.ft.
Indirect water heating surface	19.3 sq.ft.
Superheating surface	5.3 sq.ft.
Total heating surface	43.3 sq.ft.

Ratio of total heating surface to grate surface	10.8
Ratio of direct heating surface to total heating surface	0.43
Ratio of minimum draft area to grate surface	0.117

An exterier view of the boiler is shown in Fig.1. Fig.2 shows the construction of the grate, while Figs.3,4,5,& 6, show the arrangement of the heating surface.

Flues: For the first five tests the furnace was connected by a 10" galvanized-iron smoke pipe to a brick chimney as may be seen in Fig.7. The dimensions of the chimney and smoke pipe are as follows:-

Inside dimensions of chimney (nominal)	8"x16"
Height of chimney above grate	35 ft.
Diameter of pipe connecting to chimney	10 in.
Length of pipe connecting to chimney	29 ft.
Number of elbows in pipe	3

In the remaining tests a galvanized iron stack was substituted for the chimney. This arrangement is shown in Fig.8. The dimensions are as follows:-

Diameter of stack	14 in.
Height above grate	39'-4"

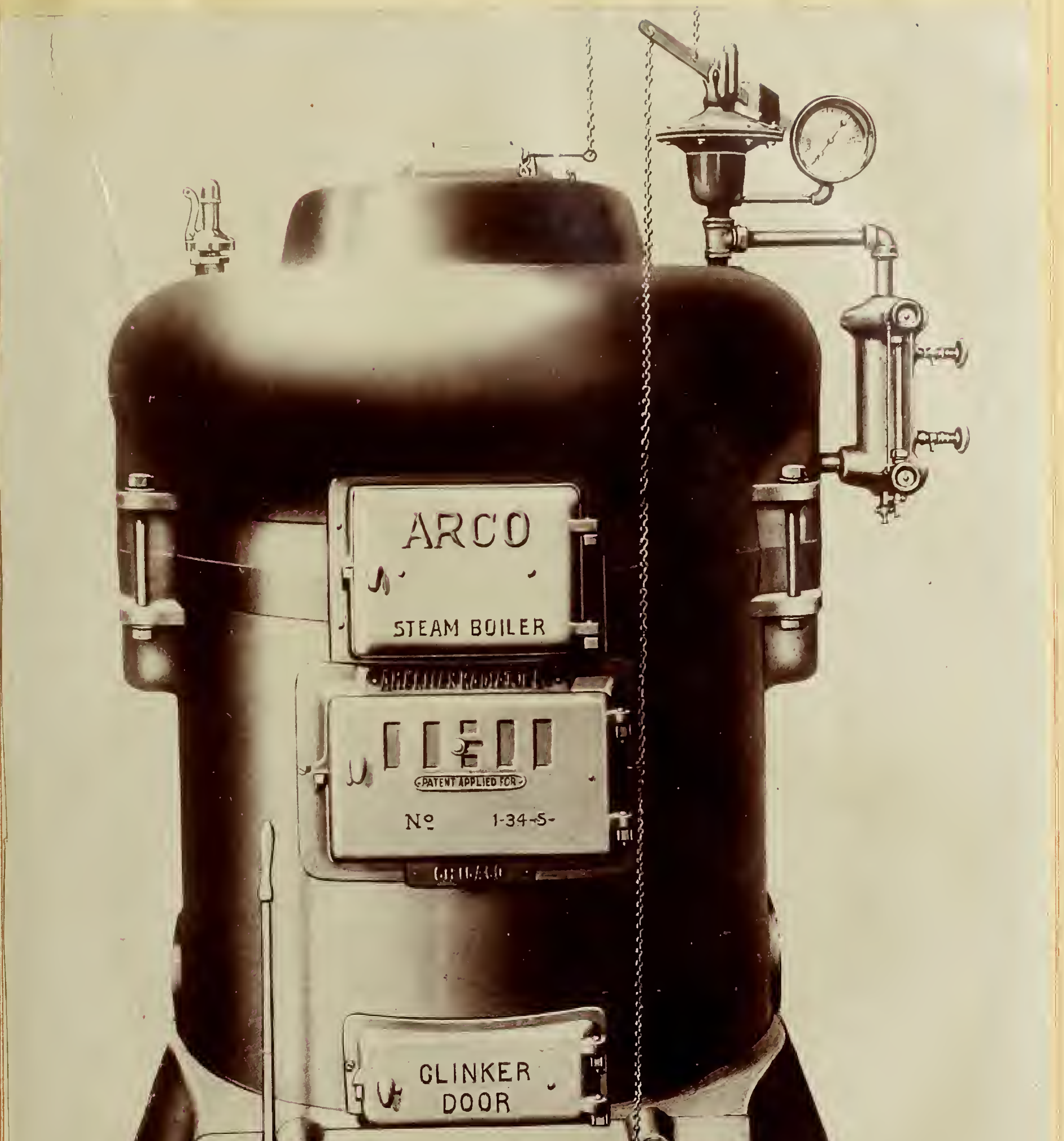
ARCO
STEAM BOILER
AMERICAN RADIATOR
PATENT APPLIED FOR
Nº 1-34-S-
CHICAGO
CLINKER DOOR
1905

Fig. 1.

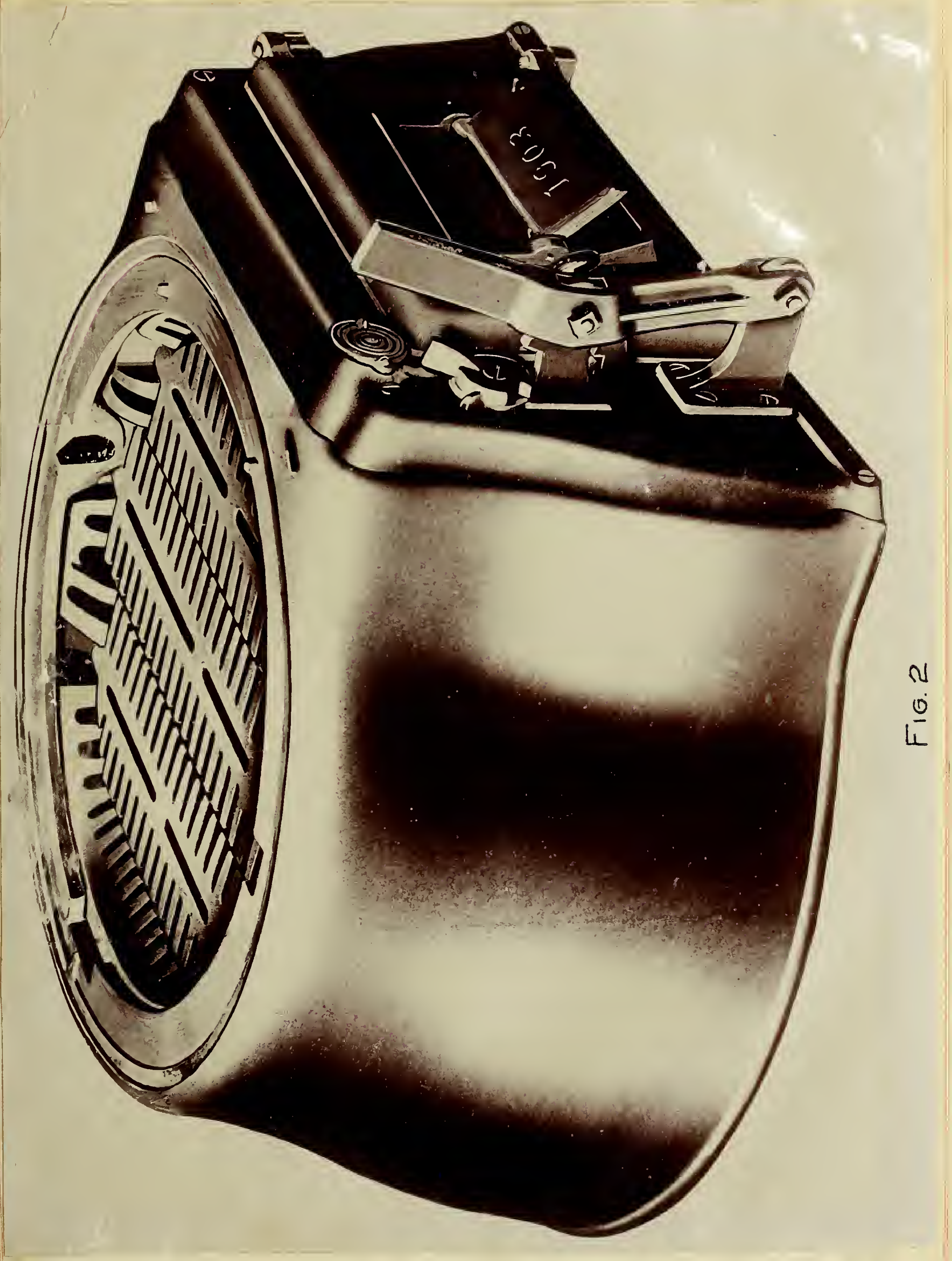

Fig. 2

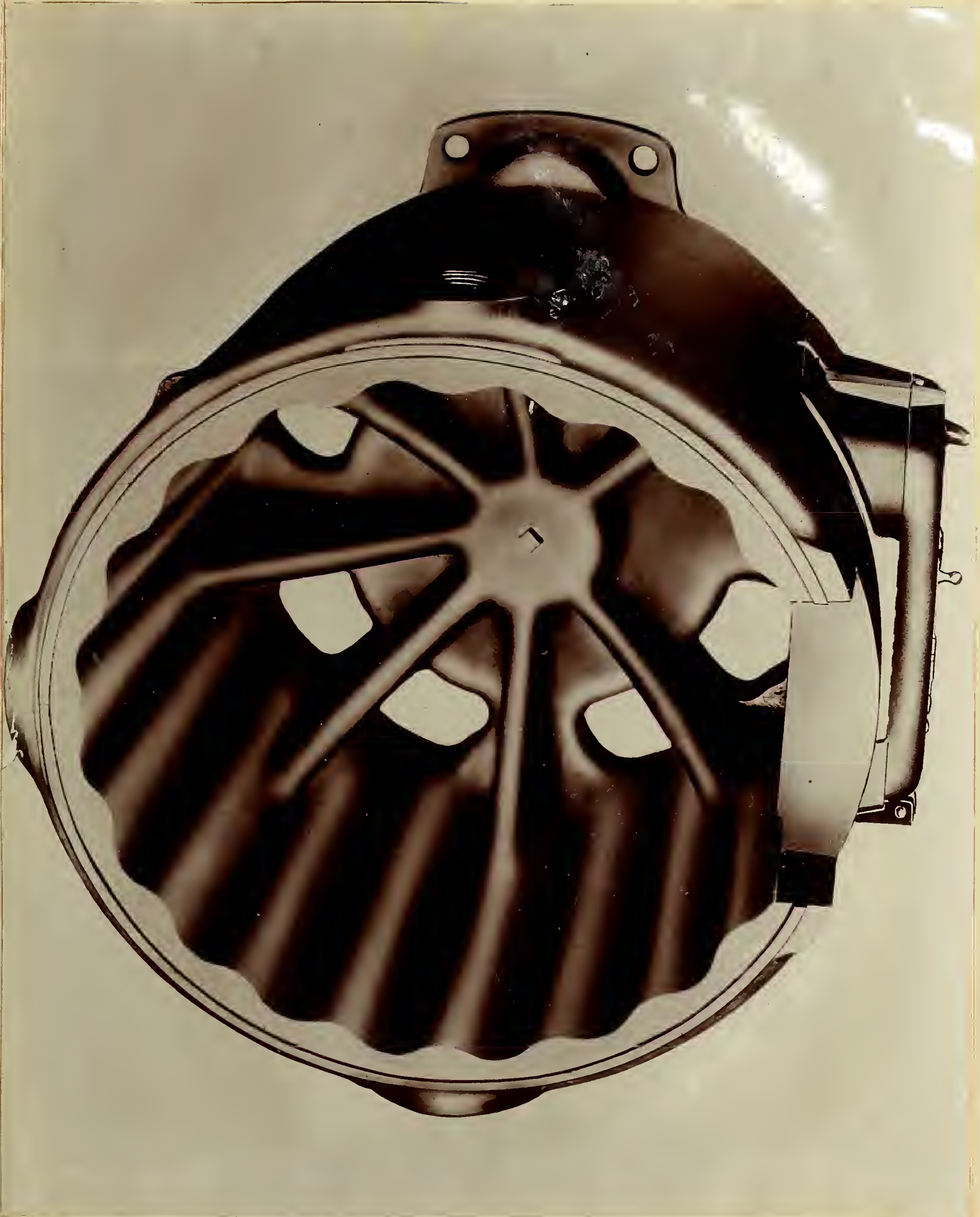

FIG. 3.

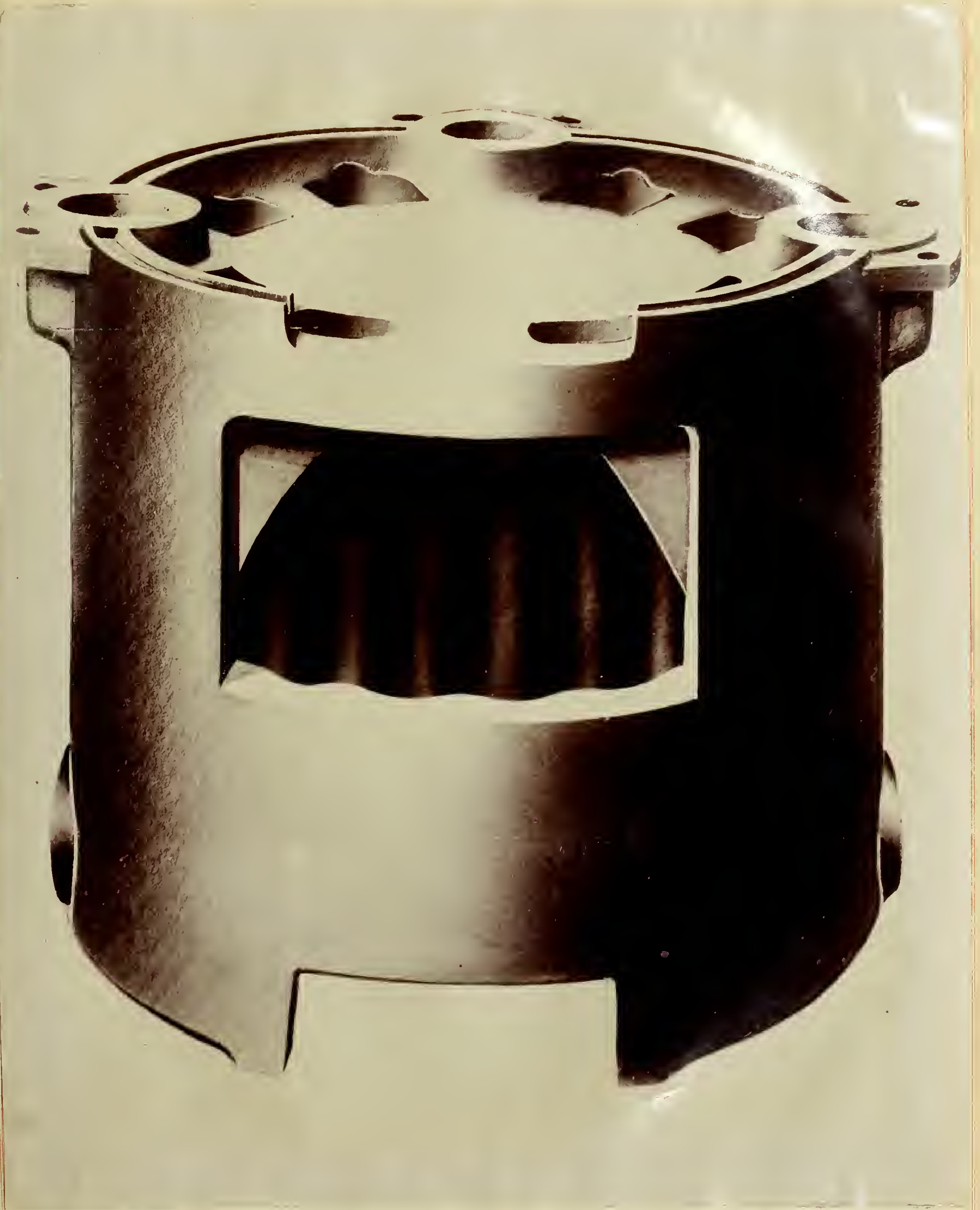

FIG. 4.

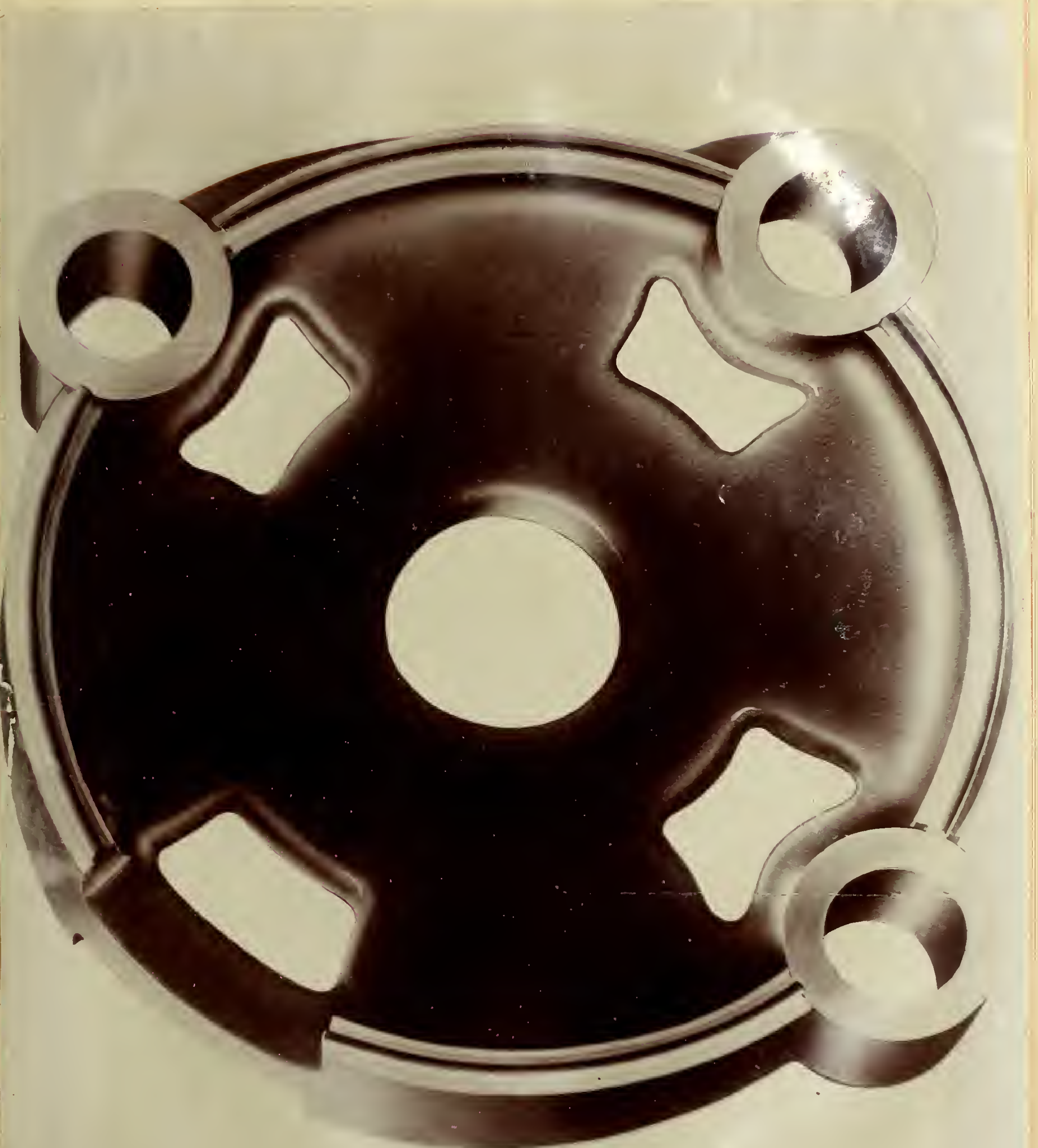

FIG. 5

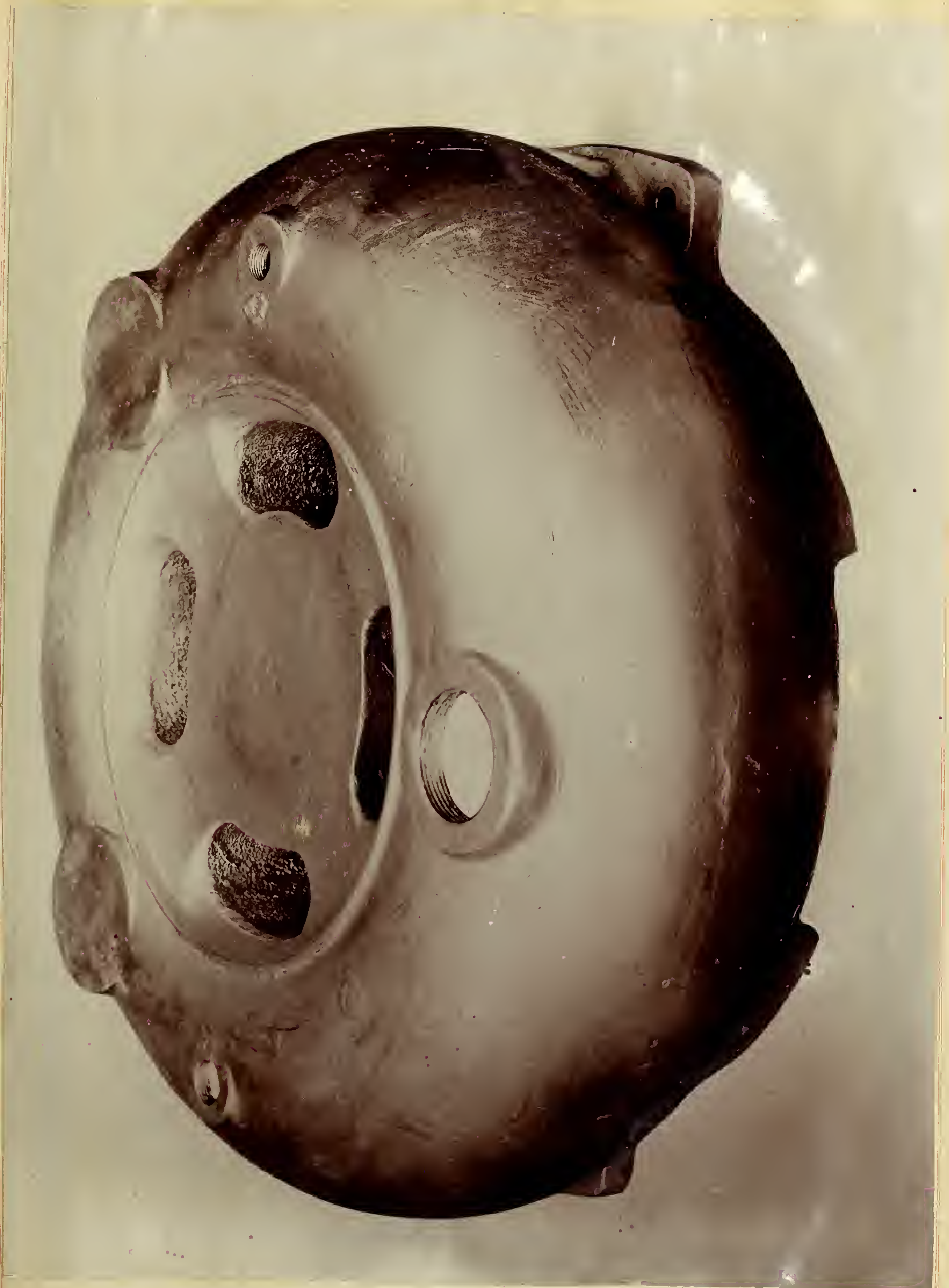

FIG. 6.

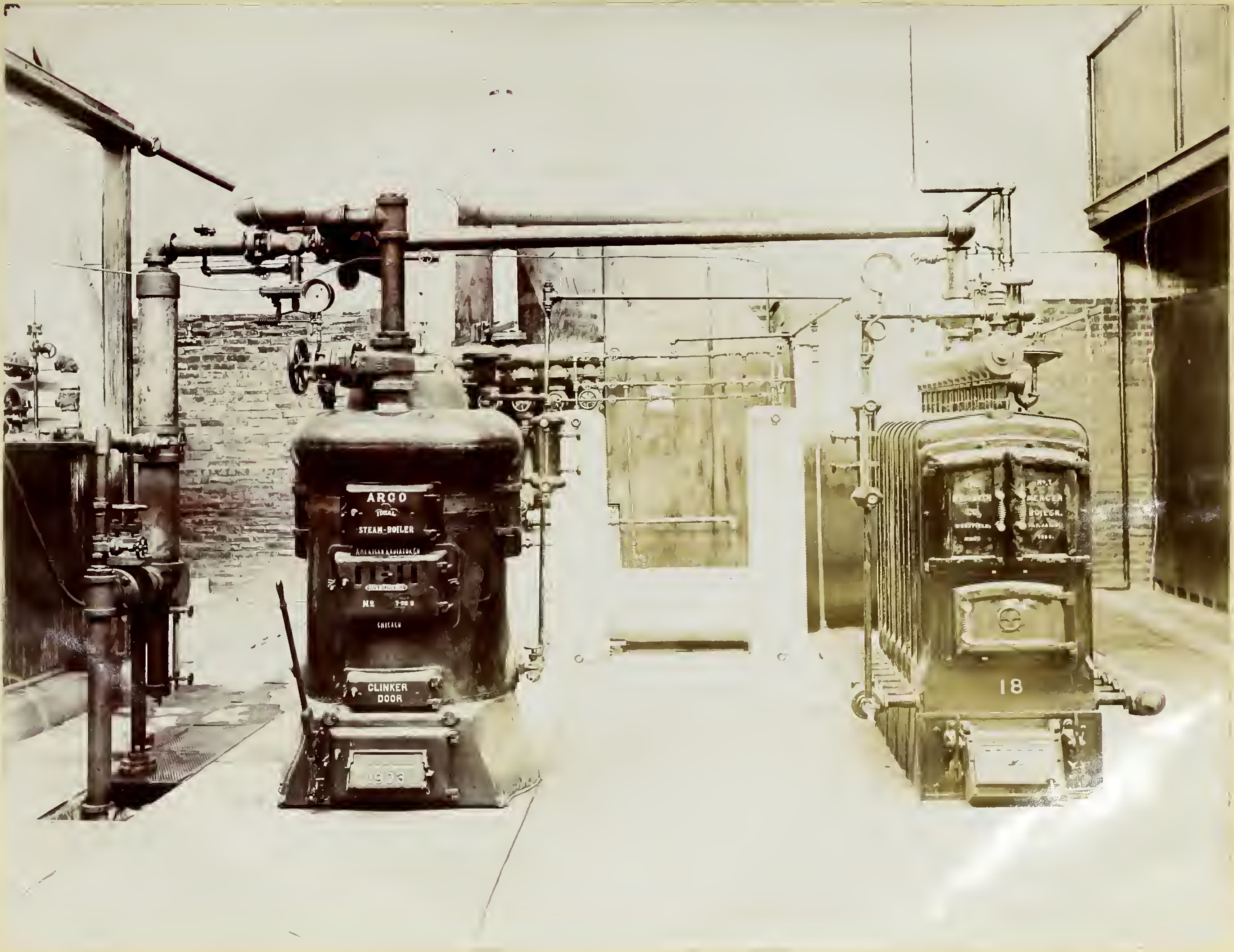
ARGO
IDEAL
STEAM-BOILER
AMERICAN RADIATOR CO
CHICAGO
CLINKER DOOR
18

FIG. 7.

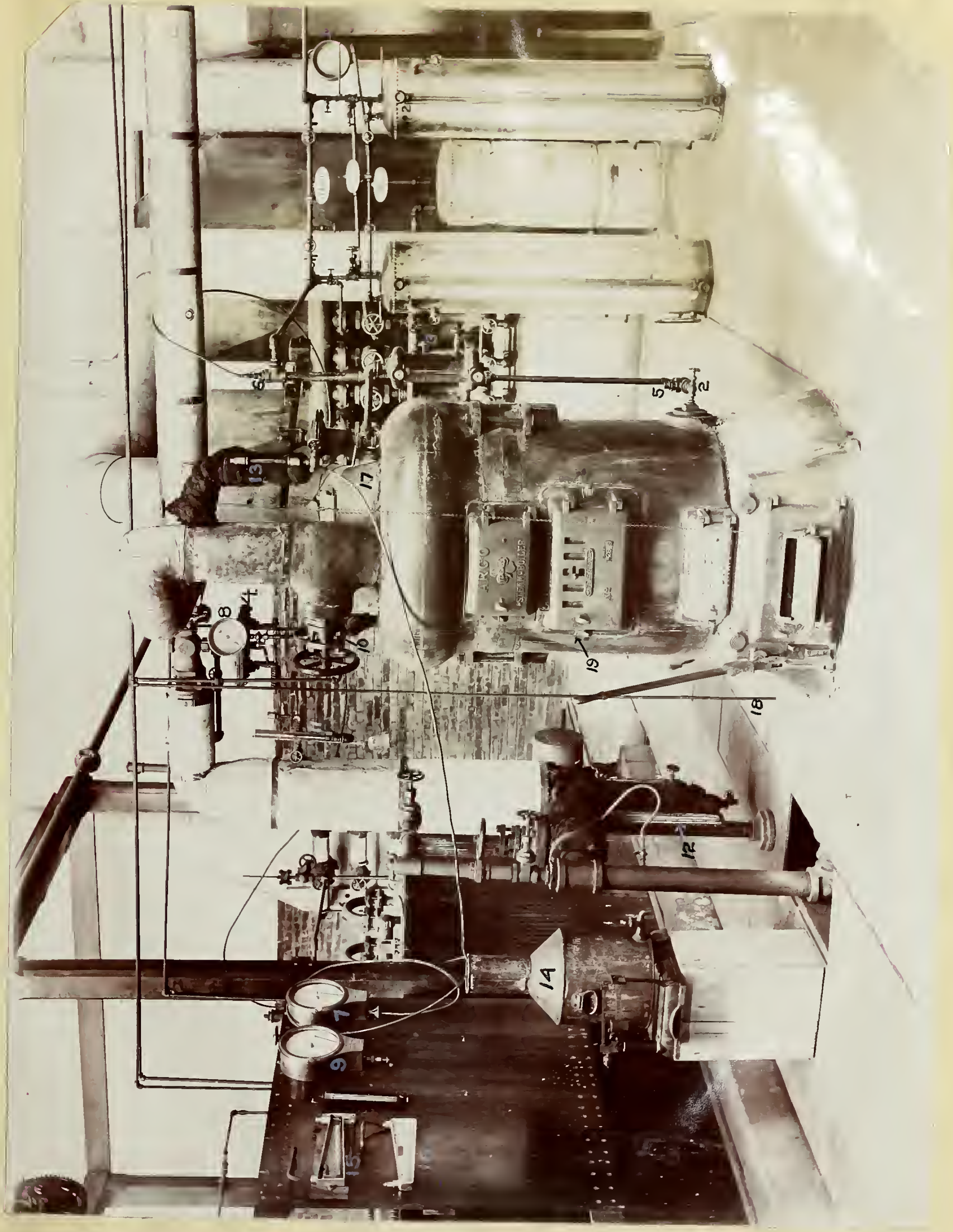
20
6
13
17
4
8
16
19
18
5
2
12
14
7
9
15

Fig. 8.

Diameter to pipe connecting to stack	10 in.
Length of pipe connecting to stack	12'-3"
Number of elbows	2
Number of thirty-degree bends	1
Height of center of horizontal pipe above grate	8'

The reasons for making this change will be given in the discussion.

Feed Tanks:- The feed water apparatus consisted of one receiver and two calibrated feed tanks. These three tanks were galvanized iron range boilers. Their setting can be seen in Fig.7 and Fig.8. The change in setting was made necessary by the erection of the smoke stack mentioned. In the two cases the operation of the apparatus was identical.

In order to obtain feed water conditions similiar to return water conditions in actual steam heating systems, and to prevent scale being formed in the boiler, which would result if water were used directly from the mains, the water of condensation from the heating coils of the laboratory was used to feed the boiler.

Referring to Fig.9, the operation of these tanks is as follows:-

The water from the coils passes through pipe a into the receiver 3. To fill tank 1, air vent f, bleeder valve k,

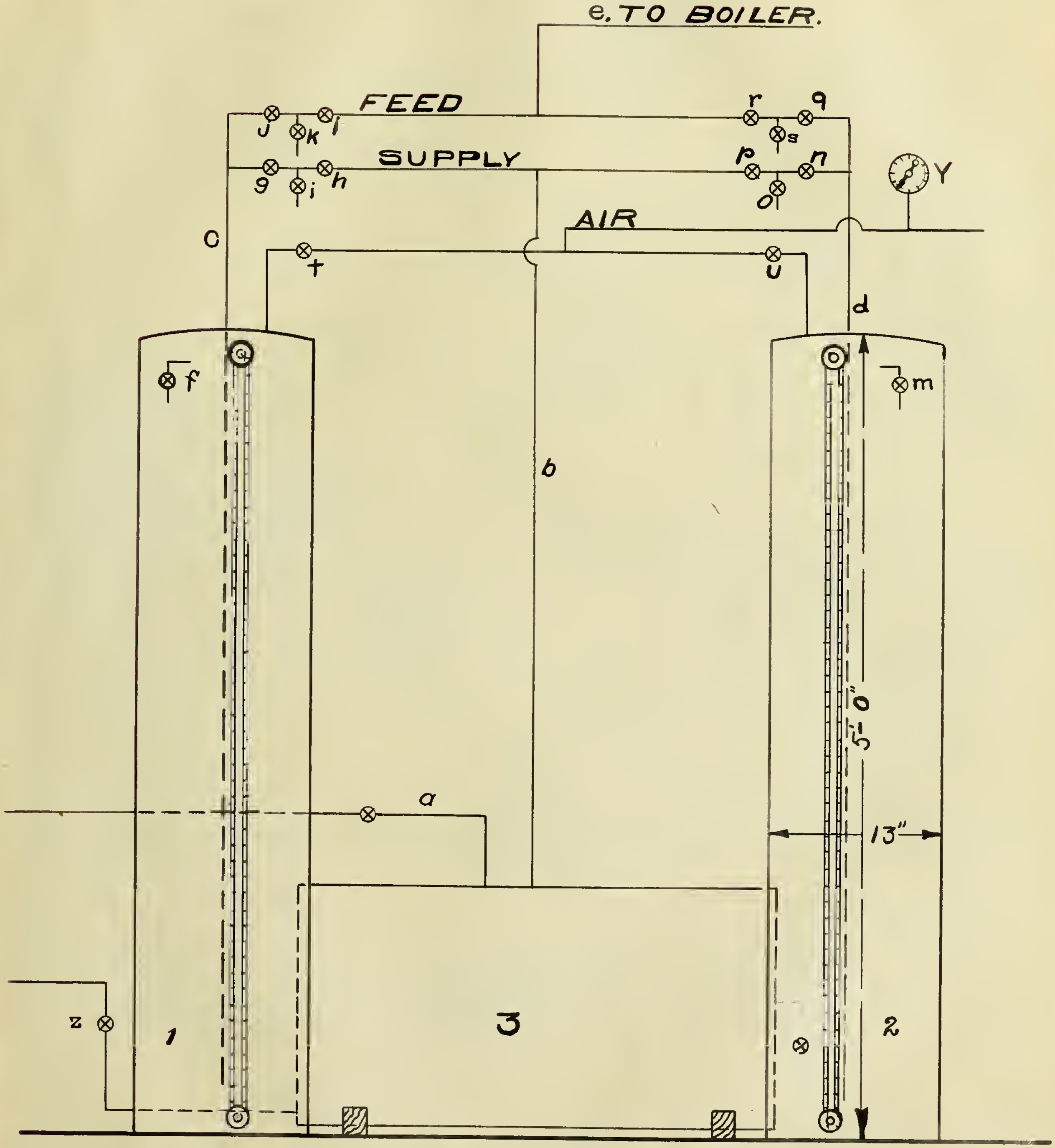
e. TO BOILER.
FEED
SUPPLY
AIR
j
k
l
r
q
s
g
i
h
p
n
o
Y
c
t
u
d
f
m
b
a
z
1
3
2
5'-0"
13"

FIG.9 - FEED TANKS

and supply valves g and h were opened, air valve t, and feed valves j and k were closed. The steam pressure on the heating coils forced the water from 3 through pipes b and c, into tank 1. When the tank was filled to the top mark on the scale, the water overflows through valve f. Valves g and h were then closed and i opened. The object of the bleeder valves, i, k, s, and o, is to detect any leakage which might occur past the shut-off valves g, 1, r, and n. After the water stopped overflowing, f and k were closed, and j, 1, and t were opened. The air pressure in the tank forced the water from the bottom of the tank through c into the feed pipe e, which leads to the boiler. While tank 1 was feeding the boiler, tank 2 was being filled from the receiver in the same way that tank 1 was filled. When 1 was nearly empty, j and i were closed, and water from 2 was fed to the boiler, and_1was refilled. In this way 1, and 2 were used alternately for feeding the boiler. The air pressure as shown by gage 1 Fig.8, had to be great enough to feed the water against the pressure in the boiler. The amount fed to the boiler was regulated by the needle valve 2 and globe valve 3 Fig.8.

Reducing Valve:- The pressure reducing valve shown at 4, Fig 8 is size 1-1/2"x3", made by the Foster Engineering Co., Newark, N.J.

Separator:- The separator is shown in Fig.10. The 3 in. pipe 1 extends to the lower end of the 7 in. pipe 2. The steam passes down the 3 in. pipe, is reversed in direction, the moisture passing into the graduated receiver 3, and the dry steam passes out through pipe 4, through the orifice contained between the faces of the union 5, and into the exhaust 6. The valve 7 is a by-pass to permit the steam to pass out without going through the orifice. The orifice may be removed when the by-pass is open and valves 8 and 9 are closed.

Orifice:- The amount of steam allowed to pass into the exhaust, or the rate at which the boiler works, was controlled by an orifice placed between the faces of the union 5, Fig.10. This orifice consisted of a round hole in a 1/32" brass plate. The diameter of the orifice was calculated by Napier's formula

$$W = \frac{a\ p_2}{42} \sqrt{\frac{3(p_1 \quad p_2)}{2\ p_2}}$$

In which

W = weight of steam flowing per second

p_2 = absolute pressure in exhaust

p_1 = absolute pressure before orifice

a = area of orifice in square inches.

The orifice was calculated for p_2 equal to atmospheric pressure. W was taken at 150 lbs. per hour, which is about

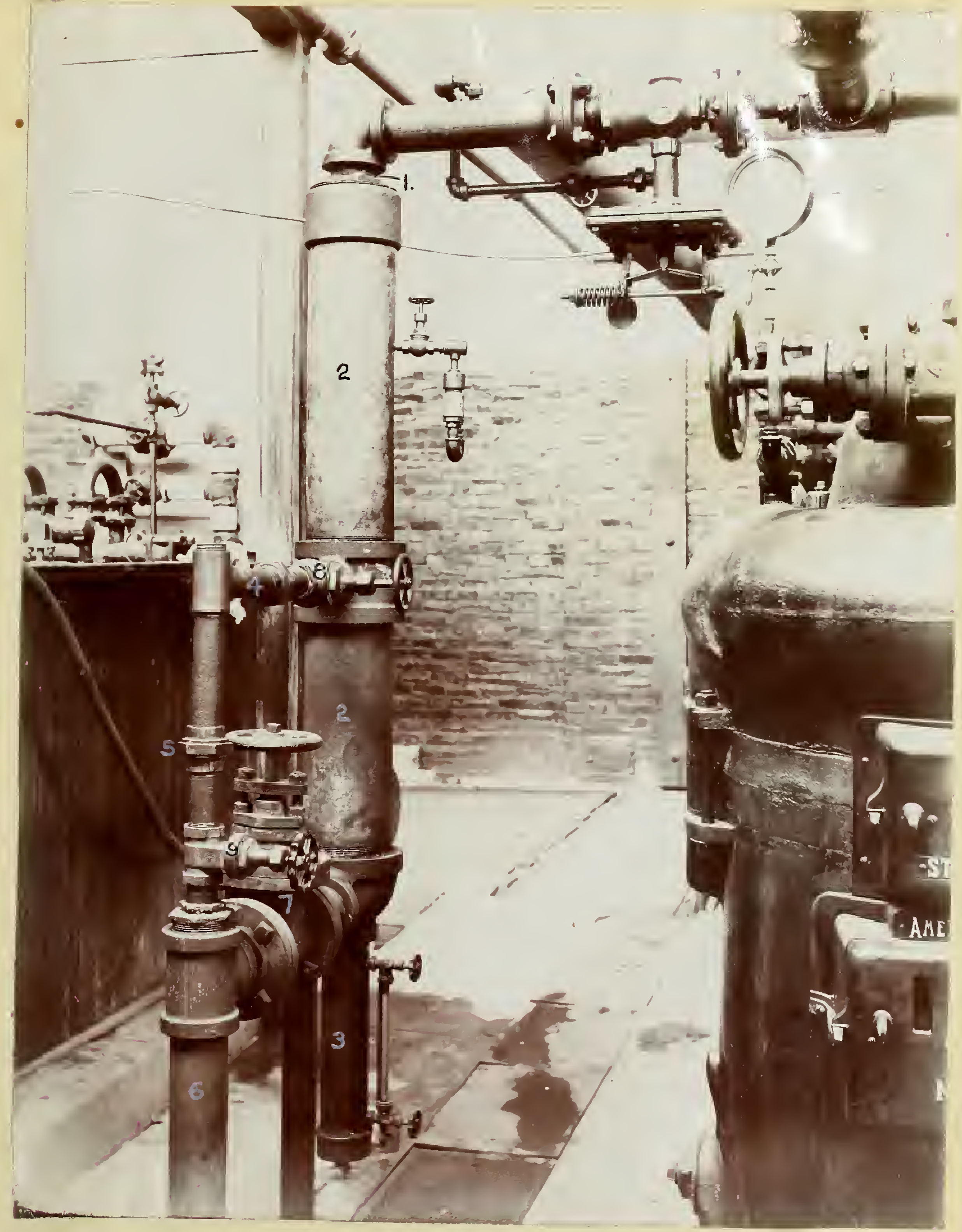
1.
2
2
3
4
5
6
7
8
9
ST
AME

FIG. 10.

75 percent of the capacity of the boiler, or the rate of 600 sq.ft. of radiation. The pressure p_1 was taken at 2 lbs. gage. These values gave an orifice 0.625 inches in diameter. A preliminary test was run using this orifice, but as the pressure in the exhaust was greater than atmospheric pressure, the discharge was only about 130 lbs. per hour. An orifice 0.672 inches in diameter was then tried. It gave a discharge of about 150 lbs. per hour, so was used throughout the tests.

Thermometers:- The temperature of the feed water was taken by two methods;

(a) A mercury thermometer was placed in a thermometer cup at 5 Fig.8.

(b) A Bristol recording pyrometer was used. The bulb was placed in a thermometer cup at 6 Fig.8. The recording mechanism was placed on the gage board as shown at 7 Fig.8.

Pressure Gages:- The boiler steam pressure was taken by two methods;

(a) By a Bourdon steam gage made by the Ashcroft Mfg. Co. placed on the boiler at 8, Fig.8.

(b) By a Bristol recording pressure gage. The gage w was placed on the board as shown at 9 Fig.8 and connected to the boiler at 10 by a 1/4" wrought iron pipe.

The pressure in the separator was taken by a mercury column 11 Fig.8.

The exhaust pressure was taken by a mercury "U" tube, 12 Fig.8, calibrated in inches.

A Crosby Bourbon gage, 1 Fig.8, was used to determine the air pressure.

Calorimeter:- A separating calorimeter shown at 13 Fig.8 was used, in connection with the condensing can 14 Fig.8, resting on scales.

Draft Gages:- The drafts were taken by two differential draft gages, 15 and 16 Fig.8, using kerosene as the liquid. Gage 15 is for the flue draft and is connected to the flue at the rear end of hood 17 Fig.8. Gage 16 measures the draft over the fire, tube 18 being inserted in hole 19 for each reading.

Scales:- The scales used for weighing the coal were ordinary platform scales reading to tenths of pounds.

The scales used for weighing the condensed steam from the calorimeter were small platform scales reading in ounces.

Sample Cans:- Three covered galvanized iron cans were used to hold the samples of coal, ash, and refuse.

Calibration of Apparatus:-

The correctness of the mercury thermometer was established by means of a hypsometer.

The pressure gage for the boiler was compared with a

mercury column and a calibration curve was drawn for correcting the readings taken in the tests.

The Bristol recording pressure gage was tested by means of a Crosby gage tester and found to be correct.

The correctness of the scales was established by the use of standard test weights.

The boiler was calibrated in the following manner:- It was filled with water at 75 degrees F. until the level in the glass was 6-1/2 inches. Amounts of ten pounds were drawn off through the blow-off cock until the water in the glass was very near the zero mark on the scale. The water level was read for each 10 lb. decrement. Chart 1 was drawn from these values to show the correction in pounds for various differences in water level. The remaining water was drawn off and weighed. The weight of water in the boiler at 3-1/4" glass was then determined. This weight divided by the weight per cubic foot of water at 75 degrees F. gave the cubic feet of water space below the 3-1/4" mark. This value was found to be 4.31 cu.ft.

Each of the feed tanks was calibrated in the following manner:- The tank was filled with water at 75 degrees F. to within 1/2" of the top of the gage glass. A mark was placed on the scale level with the water in the glass. Quantities of one pound each were drawn from the tank and marks were made on the

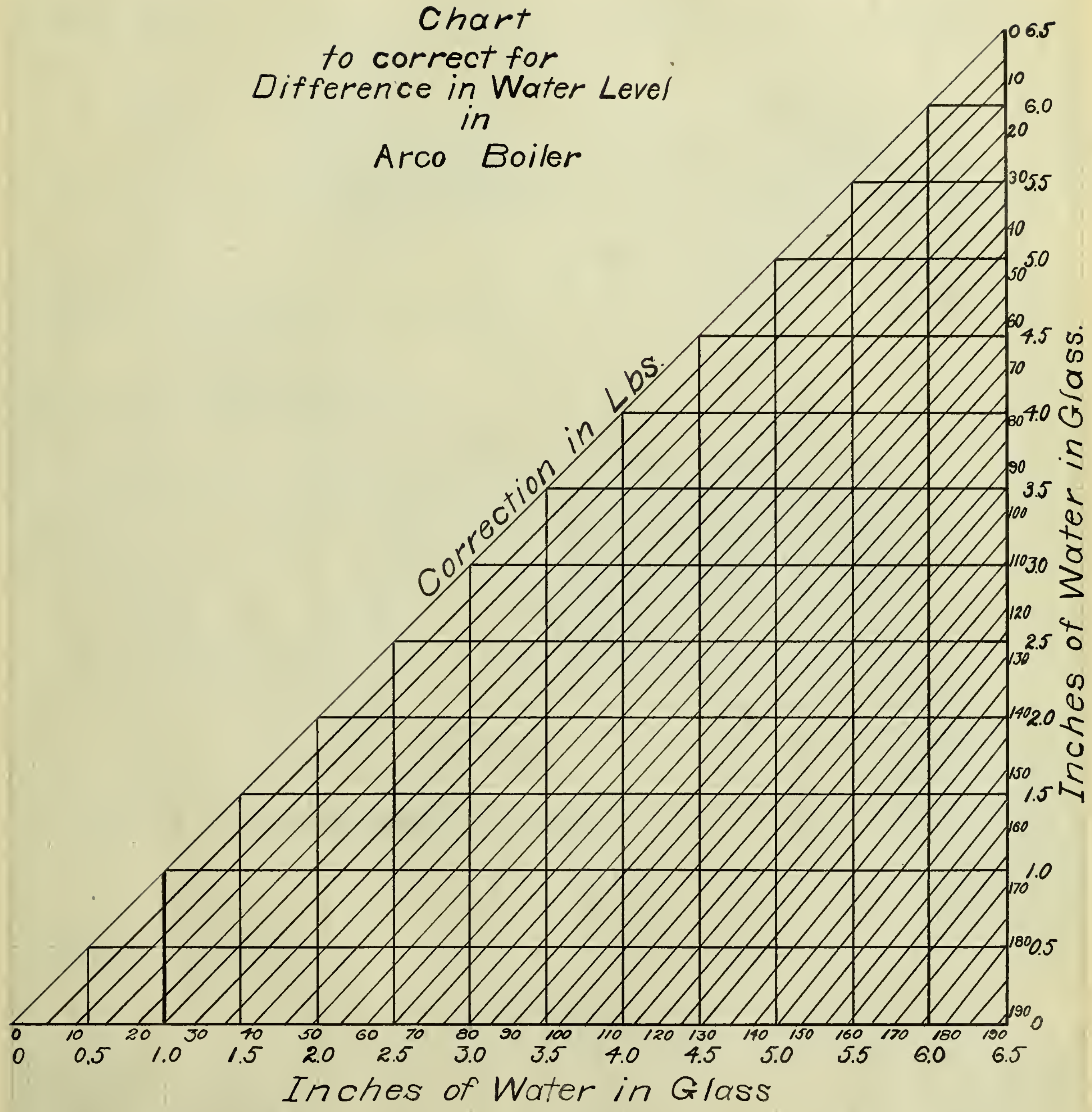
Chart
to correct for
Difference in Water Level
in
Arco Boiler
Correction in Lbs.
Inches of Water in Glass
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190
0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5
Inches of Water in Glass.
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190
6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0

CHART- I.

scale for corresponding water levels until the water was within about 1/2" of the bottom of the glass. The remaining water was drawn out and weighed. Then the total weight in the tanks was determined and marked on the scale at intervals of five pounds. Since these readings are for a temperature of 75 degrees, a correction must be made for th higher temperatures at which the water is fed to the boiler. From the ratio of specific weights at different temperatures, the corrected readings were determined. These corrections appear in Tables 1and 2.

Manner of Conducting Tests:-

Method of Starting and Stopping; The standard method of starting and stopping tests was used. At the start, steam was raised to the working pressure, exhaust valve 8 Fig.10 was closed to prevent the pressure from dropping. All the fire was rapidly removed from the grates, the ash pit was cleaned, and a weighed quantity of wood and coal was placed in the furnace as quickly as possible. The exhaust valve was opened and the wood was ignited. At this instant the time and all the readings were taken.

About a half hour before the close of the test, the fire was cleaned. Ten minutes before the end, the ash was cleaned from the pit and weighed. When the coal which remained on the grates after cleaning had burned very low, the test was

FEED WATER CORRECTION TABLES FOR HOUSE HEATING BOILERS.

WEIGHT AS READ.	TEMPERATURE OF FEED WATER.								
	120°	125°	130°	135°	140°	145°	150°	155°	160°
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
3	3.0	3.0	3.0	3.0	3.0	3.0	2.9	2.9	2.9
4	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9
5	5.0	5.0	4.9	4.9	4.9	4.9	4.9	4.9	4.9
6	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
7	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9
8	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.8	7.8
9	8.9	8.9	8.9	8.9	8.9	8.9	8.8	8.8	8.8
10	9.9	9.9	9.9	9.9	9.9	9.8	9.8	9.8	9.8
20	19.8	19.8	19.8	19.7	19.7	19.7	19.7	19.7	19.7
30	29.7	29.7	29.7	29.6	29.6	29.5	29.5	29.4	29.4
40	39.7	39.6	39.6	39.5	39.4	39.4	39.3	39.2	39.2
50	49.6	49.5	49.4	49.3	49.3	49.2	49.1	49.0	49.0
60	59.5	59.4	59.3	59.2	59.1	59.0	58.9	58.8	58.7
70	69.4	69.3	69.2	69.1	69.0	68.9	68.8	68.7	68.5
80	79.3	79.2	79.1	79.0	78.8	78.7	78.6	78.5	78.3
90	89.2	89.1	89.0	88.8	88.7	88.6	88.4	88.3	88.1
100	99.1	99.0	98.8	98.7	98.5	98.4	98.2	98.1	97.9
200	198.3	198.0	197.7	197.4	197.1	196.8	196.5	196.1	195.8
300	297.4	297.0	296.5	296.1	295.6	295.2	294.7	294.2	293.7
400	396.6	396.0	395.4	394.8	394.2	393.6	392.9	392.3	391.7
500	495.7	495.0	494.3	493.5	492.7	492.0	491.2	490.4	489.6
600	594.8	594.0	593.2	592.2	591.2	590.4	589.4	588.4	587.5
700	694.0	693.0	692.0	690.9	689.8	688.8	687.6	686.5	685.4
800	793.1	792.0	790.9	789.6	788.3	787.2	785.9	784.6	783.3
900	892.2	891.1	889.8	888.3	886.8	885.6	884.1	882.7	881.2
1000	991.3	990.1	988.6	987.0	985.4	984.0	982.3	980.7	979.1
2000	1982.7	1980.2	1977.3	1974.0	1970.8	1967.9	1964.7	1961.5	1958.3
3000	2974.0	2970.3	2965.9	2961.0	2956.1	2951.9	2947.0	2942.2	2937.4
TEMPS.	120°	125°	130°	135°	140°	145°	150°	155°	160°

SCALES ON TANKS READ CORRECT AT 75° F.

TABLE I.

FEED WATER CORRECTION TABLES
FOR
HOUSE HEATING BOILERS.

WEIGHT AS READ.	TEMPERATURE OF FEED WATER.							
	165°	170°	175°	180°	185°	190°	195°	200°
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	2.0	2.0	1.9	1.9	1.9	1.9	1.9	1.9
3	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
4	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
5	4.9	4.9	4.9	4.9	4.9	4.8	4.8	4.8
6	5.9	5.9	5.9	5.8	5.8	5.8	5.8	5.8
7	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
8	7.8	7.8	7.8	7.8	7.8	7.7	7.7	7.7
9	8.8	8.8	8.8	8.7	8.7	8.7	8.7	8.7
10	9.8	9.8	9.7	9.7	9.7	9.7	9.7	9.6
20	19.5	19.5	19.5	19.4	19.4	19.4	19.3	19.3
30	29.3	29.3	29.2	29.2	29.1	29.1	29.0	28.9
40	39.1	39.0	39.0	38.9	38.8	38.7	38.7	38.6
50	48.9	48.8	48.7	48.6	48.5	48.4	48.3	48.2
60	58.6	58.5	58.4	58.3	58.2	58.1	58.0	57.9
70	68.4	68.3	68.2	68.1	67.9	67.8	67.7	67.5
80	78.2	78.1	77.9	77.8	77.6	77.5	77.3	77.2
90	88.0	87.8	87.7	87.5	87.3	87.2	87.0	86.8
100	97.7	97.6	97.4	97.2	97.0	96.9	96.7	96.5
200	195.5	195.2	194.8	194.4	194.1	193.7	193.3	192.9
300	293.2	292.7	292.2	291.7	291.1	290.6	290.0	289.4
400	390.9	390.3	389.6	388.9	388.2	387.4	386.6	385.8
50.0	488.7	487.9	487.0	486.1	485.2	484.3	483.3	482.3
600	586.4	585.5	584.4	583.3	582.3	581.2	580.0	578.7
700	684.2	683.0	681.8	680.6	679.3	678.0	676.6	675.2
800	781.9	780.6	779.2	777.8	776.4	774.8	773.3	771.6
900	879.6	878.2	876.6	875.0	873.4	871.7	869.9	868.1
1000	977.4	975.8	974.0	972.2	970.5	968.5	966.6	964.5
2000	1954.7	1951.5	1948.0	1944.4	1940.9	1937.1	1933.2	1929.0
3000	2932.1	2927.3	2922.0	2916.7	2911.4	2905.6	2899.8	2893.5
TEMPS.	165°	170°	175°	180°	185°	190°	195°	200°

SCALES ON TANKS READ CORRECT AT 75° F.

TABLE 2.

stopped in the following manner:- All readings were taken and the time was recorded. Immediately all the fire was shaken from the grates, placed in a tight galvanized iron can, and weighed. This partially burned coal was designated as refuse.

Method of Firing:- After the fire was nicely started the coal was fired in fifty-pound quantities, except in the tests on anthracite, in which about 100 lbs. was fired at a time.

The boiler pressure was kept nearly constant by the automatic draft regulator. When the coal had burned so low that the pressure began to fall with the draft open, a new amount of coal was fired.

Sampling Coal and Ash:- Each time coal was delivered to the scales a sample of three or four pounds was taken and placed in a tight galvanized iron can.

The coal sample, total ash, and total refuse were ground and a sample of each was taken by the "quartering" method. These samples were sent to the Chemistry Department for analysis.

Measurement of Water:-

The weight of feed water was determined by reading the weight in the feed tanks and correcting for temperature as read from the mercury thermometer.

Feed Water Temperature:- The recording thermometer was used

as a check on the mercury thermometer. The mercury thermometer readings were used in the computations.

Pressures:- The automatic draft regulator was adjusted to maintain a pressure of about five pounds per square inch. The pressure in the separator is maintained at two pounds by adjusting the reducing valve. The boiler pressure used in calculations was the corrected pressure from the Bourbon gage on the boiler.

Quality of Steam:- The quality of steam was taken continuously, except when changing the water in the condenser can. The amount of dry steam from the calorimeter was determined by the increase in weight in the condenser can. The amount of moisture was read from the scale on the calorimeter.

Analysis of Coal, Ash, and Refuse:- The coal, ash, and refust were analyzed by the Chemistry Department of the University of Illinois.

Duration of Tests and Time of Readings:- Each test lasted about eight hours. The time of stopping was governed by the condition of the fire, which was allowed to burn low toward the end of the test. Every ten minutes the following readings were taken:-

Boiler Pressure,
Separator Pressure,
Exhaust Pressure,

Flue Draft,

Fire-box Draft,

Feed Water Temperature,

Weight of Feed Water,

The water level in the boiler and the temperature of the laboratory were read every hour.

The weight of the coal was recorded when fired.

Log Sheets:-

The following tables contain the corrected data for the various tests.

TESTS OF DIFFERENT COALS IN A RESIDENCE HEATING BOILER (STEAM)

LOG SHEET

TEST No — 1

DATE — APRIL 2, '07

KIND OF COAL HERRIN #2 WASHED

No	TIME	PRESSURES					TEMP OF FEED WATER	WEIGHT FEED WATER	WEIGHT OF COAL
		STEAM			DRAFT				
		BOILER	SEPARATOR	EXHAUST	FLUE	FIRE-BOX			
1	9:20	3.2	1.75		.050	.060	184.0	0	11.0
2	:30	9.1	2.00		.050	.050	172.0	0	6.0
3	:40	10.0	1.85		.050	055	161.0	0	11.0
4	50	8.9	1.90		.060	.070	121.0	4.0	12.0
5	10:00	9.3	2.02		.050	.060	114.0	49.1	10.0
6	:10	9.5	1.95		.050	.060	107.0	6.4	0
7	:20	7.8	1.85		.055	.065	111.0	27.7	0
8	:30	9.4	2.03		.050	.060	109.0	26.2	23.0
9	:40	9.0	2.00		.065	.065	111.0	55.0	12.0
10	:50	9.1	1.85		.060	.060	110.0	52.1	0
11	11:00	11.4	1.90		.050	.060	155.0	22.1	0
12	:10	7.0	2.00		.060	.070	163.0	0	0
13	:20	9.8	1.92		.055	065	168.0	0	15.0
14	:30	10.1	2 00		.075	.085	169.0	34.6	0
15	:40	10.0	2.00		.090	.100	171.0	28.3	0
16	:50	10.1	1.95		.065	.080	157.0	11.8	20.0
17	12:00	9.6	2.00		.060	.080	168.0	35.6	0
18	:10	12.9	2.07		.110	.120	168.0	53.2	0
19	:20	8.6	2.00		.065	.080	181.5	87.5	20.0
20	:30	10.1	1.90		.070	.090	173.0	40.0	0
21	:40	11.0	1.90		.055	.070	163.0	0	19.0
22	:50	10.9	1.90		.050	.065	155.0	0	0
23	1:00	8.1	1.97		.060	.075	150.0	0	0
24	:10	7.5	1.85		.050	.065	149.0	0	0
25	:20	14.0	2.05		.050	.065	122.0	5.5	0
26	:30	11.8	2.05		.060	.085	162.0	41.2	0
27	:40	5.3	1.85		.080	.090	160.0	41.7	0
28	:50	8.8	1.90		.050	.065	167.0	20.0	0
29	2:00	9.0	1.92		.090	.100	162.0	0	0
30	:10	13.9	2 05		.080	.100	167.0	38.6	0
31	:20	14.9	2.00		.085	100	163.0	34.2	0
32	:30	10.7	2.05		.075	.095	162.0	16.2	31.0
33	:40	9.7	2.03		.080	.095	167.0	43.0	0
34	:50	12.1	1.85		.100	.110	162.0	48.5	0
35	3:00	9.8	1.95		.095	.115	145.0	6.4	0
36	:10	9.2	2.00		.090	.110	125.0	1.0	0
37	:20	12.1	2.00		.085	.100	119.0	5.9	0
38	:30	6.7	2.00		.110	.100	171.0	52.8	20.0
39	:40	12.1	1.97		.110	.100	152.0	0	0
40	:50	4.6	2.00		.120	.090	159.0	17.2	0
41	4:00	8.0	2.00		.115	.080	163.0	22.0	0
42	:10	11.2	1.9		.105	.080	162.0	36.7	0
43	:20	8.7	1.85		.070	.080	152.0	11.3	0
44	:30	10.6	1.95		.080	.130	153.0	29.4	23.5
45	:40	9.5	1.85		.090	.100	153.0	5.9	0
46	:50	10.0	1.87		.085	.125	155.0	0	17.0
47	5:00	9.2	1.90		.085	.160	154.0	22.8	0
48	:10	7.8	1.83		.080	.180	164.0	79.2	0
49	:20	8.0	1.84		.075	.130	160.0	0.	0
TOTAL —								1113.1	261.0
AVERAGE —		9.6	1.94		.073	.088	152.5		

REMARKS —

TESTS OF DIFFERENT COALS IN A RESIDENCE HEATING BOILER [STEAM]

LOG SHEET

TEST No.— 2

KIND OF COAL HERRIN #2 WASHED.

DATE— APRIL 11, 1907

No	TIME	PRESSURES					TEMP. OF FEED WATER	WEIGHT FEED WATER	WEIGHT OF COAL
		STEAM			DRAFT				
		BOILER	SEPARATOR	EXHAUST	FLUE	FIRE-BOX			
1	3:20	1.1	2.0		.075	.110	186.0	0	15.0
2	:30	0.0	0.08		.085	.130	186.0	46.9	
3	:40	2.1	1.70		.090	.140	163.0	0.0	21.0
4	:50	3.9	1.95		.095	.145	150.5	0.0	14.0
5	4:00	3.6	2.15		.090	.140	184.5	59.2	
6	:10	0.3	2.00		.075	.115	160.0	8.3	50.0
7	:20	4.1	1.95	.90	.090	.140	166.0	5.4	
8	:30	5.3	2.00	.90	.085	.130	178.0	36.4	
9	:40	5.2	2.00	1.00	.080	125	175.0	50.7	
10	:50	5.3	2.00	.90	.095	.145	189.0	57.6	
11	5:00	0.3	:20	.30	.085	.125	189.0	33.4	50.0
12	:10	3.3	2.22	1.00	080	.125	173.5	15.6	
13	:20	5.2	1.95	.90	080	.130	181.0	27.2	
14	:30	5.0	1.95	.90	.090	.135	182.0	60.3	
15	:40	5.2	1.95	.90	.090	.140	183.0	48.5	
16	:50	1.1	.80	.60	.085	.130	172.0	8.8	50.0
17	6:00	4.1	2.02	1.00	.085	.130	177.0	27.2	
18	:10	5.3	1.95	1.00	.080	.120	175.0	37.0	
19	:20	5.0	1.97	1.00	.075	.115	174.0	38.0	
20	:30	5.3	1.95	1.00	.070	.135	173.5	44.9	
21	:40	5.7	1.97	1.00	.085	.120	192.0	47.4	
22	:50	1.3	.80	.70	.075	.120	190.0	74.6	50.0
23	7:00	3.9	2.03	1.00	.075	.115	189.0	74.6	
24	:10	5.2	1.95	1.10	.070	.115	174.5	0.0	
25	20	5.5	1.95	1.10	.070	.130	162.0	0.0	
26	:30	5.0	1.95	1.10	.080	.125	159.0	19.7	
27	:40	5.6	1.97	1.10	.080	.120	197.0	82.0	
28	:50	5.4	1.95	1.20	.075	.105	188.0	43.5	
29	8:00	0.9	.55	.60	.065	.110	170.0	0.0	50.0
30	:10	5.6	2.00	1.10	.070	.110	159.0	0.0	
31	:20	5.1	1.95	1.10	.070	.130	184.0	58.2	
32	:30	5.1	1.97	1.20	.070	.110	187.0	69.8	
33	:40	5.4	1.95	1.20	.070	.110	173.0	24.3	
34	:50	4.1	1.90	1.20	.075	.120	180.0	37.4	
35	9:00	0.5	.20	.40	.065	.105	178.0	36.9	50.0
36	:10	2.7	2.00	1.20	.065	.110	189.0	37.7	
37	:20	5.3	2.00	1.20	.065	.110	184.0	26.7	
38	:30	5.5	1.97	1.20	065	.110	182.0	34.5	
39	:40	5.5	1.97	1.20	.055	.100	181.0	32.1	
40	50	5.5	1.95	1.20	.055	.100	182.0	41.8	
41	10:00	4.7	1.90	1.20	.070	.115	181.5	39.4	
42	:10	1.8	1.25	1.10	.060	.110	181.0	47.1	50.0
43	:20	1.9	1.95	1.20	.095	.115	169.0	25.4	
44	:30	5.5	2.00	1.20	.100	.120	175.0	31.2	
45	:40	5.3	1.93	1.20	.100	.120	169.0	27.3	
46	:50	0.5	.23	.30	.08	.100	179.0	31.2	
47	11:00	2.7	1.92	1.20	10	.120	170.0	10.8	
TOTAL -								1559.0	375.0
AVERAGE -		3.86	1.72	.99	.078	.121	177.4		

REMARKS-

TESTS OF DIFFERENT COALS IN A RESIDENCE HEATING BOILER (STEAM)

LOG SHEET

TEST No — **3.**

DATE — APRIL 12, '07

KIND OF COAL HERRIN-#2 WASHED

No	TIME	PRESSURES					TEMP. OF FEED WATER	WEIGHT FEED WATER	WEIGHT OF COAL
		STEAM			DRAFT				
		BOILER	SEPARATOR	EXHAUST	FLUE	FIRE-BOX			
1	3:00	.5	1.00	.5	.115	.135	162.0	0	18.0
2	:10	5.0	1.95	.7	.130	.160	158.0	0	
3	:20	4.3	1.95	.7	.130	.140	155.0	57.3	22.0
4	:30	7.1	2.05	.8	.125	.140	152.0	23.1	10.0
5	:40	5.0	1.90	.7	.105	.125	135.0	8.9	
6	:50	6.1	2.00	.7	.150	.160	150.0	32.9	50.0
7	4:00	1.7	1.10	.5	.120	.130	149.0	37.3	
8	:10	6.9	2.00	.6	.130	.150	151.0	19.2	
9	:20	5.8	1.97	.7	.130	.150	180.0	27.2	
10	:30	6.1	2.00	.7	.120	.140	177.0	32.1	
11	:40	4.9	2.07	.8	.115	.135	156.0	6.9	
12	:50	6.9	2.15	.9	.120	.140	176.0	30.2	
13	5:00	1.7	2.07	.7	.115	.135	174.5	41.4	
14	:10	6.1	1.95	.7	.115	.135	172.0	22.9	
15	:20	6.0	2.03	.9	.120	.145	169.0	21.5	
16	:30	5.7	1.90	.7	.120	.140	170.0	27.3	
17	:40	5.3	2.00	.8	.110	.130	176.0	49.7	
18	:50	1.6	1.95	.7	.140	.170	164.0	6.8	
19	6:00	6.4	1.90	.7	.120	.140	169.0	35.6	
20	:10	10.1	1.25	.5	.115	.135	157.0	0.0	50.0
21	:20	5.6	2.05	.7	.110	.120	169.0	37.5	
22	:30	5.7	2.30	.9	.120	.150	157.0	18.7	
23	:40	5.5	1.85	.6	.110	.130	165.0	22.4	
24	:50	5.5	1.95	.7	.115	.135	171.0	40.0	
25	7:00	4.8	1.90	.7	.110	.120	162.0	17.7	
26	10	4.1	1.90	.7	.120	.130	159.0	13.7	
27	20	3.6	1.80	.7	.130	.150	169.0	49.8	
28	30	9.4	1.85	.5	.120	.130	154.0	14.8	50.0
29	40	6.8	2.05	.7	.110	.120	131.0	4.0	
30	50	7.5	2.15	.8	.140	.140	162.0	54.8	
31	8:00	5.6	2.25	.7	.120	120	166.0	46.0	
32	:10	5.7	2.07	.7	.120	.120	152.0	1.0	
33	:20	7.3	1.90	.7	.130	.130	165.0	49.4	
34	:30	6.1	1.95	.7	.140	.140	143.0	1.5	
35	:40	5.8	2.07	.7	.130	.135	159.0	44.1	
36	:50	5.7	1.90	.7	.120	125	148.0	0.0	
37	9:00	6.9	2.00	.7	.120	.130	154.0	35.3	
38	:10	2.4	2.07	.7	.120	.120	143.0	0.0	
39	:20	7.4	2.00	.7	.120	.125	167.0	55.6	
40	:30	6.1	1.90	.7	.180	.125	154.0	14.7	50.0
41	:40	6.8	2.15	.7	.160	.120	165.0	50.4	
42	:50	6.8	2.30	8	.150	.120	154.5	16.2	
43	10:00	6.1	2.05	.7	.160	.130	157.0	30.9	
44	:10	6.1	2.00	.7	.150	.120	163.0	21.0	
45	:20	5.9	2.07	.7	.170	.130	156.0	25.6	
46	:30	5.9	2.00	.7	.190	.135	158.0	24.6	
47	:40	5.0	1.90	.7	.150	.125	159.0	33.3	
48	50	5.8	1.95	.6	.160	.160	155.0	26.6	
49	11:00	4.1	1.85	.6	.160	.160	135.0	4.9	
TOTAL -								1234.8	250.0
AVERAGE -		5.70	1.94	.70	.130	.135	159.2		

REMARKS -

TESTS OF DIFFERENT COALS IN A RESIDENCE HEATING BOILER [STEAM]

LOG SHEET

TEST No – 4

DATE – APRIL 13, 07

KIND OF COAL – CHICAGO-HERRIN #2 UNWASHED.

No	TIME	PRESSURES					TEMP. OF	WEIGHT	WEIGHT
		STEAM			DRAFT		FEED	FEED	OF
		BOILER	SEPARATOR	EXHAUST	FLUE	FIRE-BOX	WATER	WATER	COAL
1	9:00	4.1	1.80	.6	.205	.12	189.0	0	20
2	:10	6.8	1.97	.6	.200	.13	176.0	28.3	
3	:20	3.6	1.80	.5	.240	.12	173.0	19.5	30
4	:30	5.2	1.83	.5	.245	.15	176.0	20.5	
5	:40	5.4	1.95	.5	.280	15	176.0	37.5	
6	:50	5.6	1.90	.5	.180	.135	172.0	21.5	
7	10:00	6.6	2.05	.6	.200	.14	168.0	23.0	
8	:10	5.0	1.87	.5	.230	.14	165.5	22.0	
9	:20	5.0	1.90	.5	.230	.145	182.0	33.9	50
10	:30	4.0	2.04	.6	.300	.12	167.0	4.9	
11	:40	8.1	2.13	.6	.210	.12	186.0	39.8	
12	:50	6.7	2.05	.6	.200	.13	171.5	27.3	
13	11:00	5.8	2.00	.5	.210	.13	165.0	18.5	
14	:10	5.9	2.00	.5	.260	.135	178.0	36.0	
15	:20	5.2	1.93	.5	.225	.125	170.0	21.0	
16	:30	5.7	2.00	.5	.270	.13	173.0	31.2	
17	:40	5.1	1.90	.5	.255	.14	165.0	20.5	
18	:50	5.9	2.00	.5	.135	.08	170.0	25.4	
19	12:00	5.5	1.95	.5	.200	.12	173.0	36.0	
20	:10	4.8	1.93	.5	.195	.105	171.5	27.3	50
21	:20	2.2	1.88	.5	.255	.10	150.0	9.8	
22	:30	5.2	2.05	.5	.180	.09	158.0	20.7	
23	:40	6.2	2.20	.5	.180	.09	164.0	34.2	
24	:50	5.9	1.93	.5	.170	11	170.0	29.3	
25	1:00	6.1	2.00	.5	.150	.09	174.0	21.9	
26	:10	5.2	1.92	.5	.200	.085	172.0	20.0	
27	:20	5.3	1.95	.4	.210	.09	171.0	41.0	
28	:30	6.6	2.03	.5	.170	.09	168.0	29.3	
29	:40	5.6	1.95	.4	.230	.09	166.0	28.3	50
30	:50	2.1	1.65	.3	.200	.085	158.0	16.7	
31	2:00	4.8	2.20	.5	.190	.09	150.0	18.7	
32	:10	6.9	2.08	.5	.190	.09	175.0	61.4	
33	:20	7.1	2.08	.5	.160	.085	166.0	20.5	
34	:30	6.0	2.00	.5	.210	.10	155.0	0	
35	:40	5.7	1.93	.4	.170	.085	148.0	0	
36	:50	6.5	2.00	.4	.170	.085	165.0	41.1	
37	3:00	5.9	1.90	.4	.220	.09	163.0	20.5	
38	:10	5.6	1.97	.4	.240	.09	163.0	45.9	
39	:20	5.2	1.90	.4	.170	.08	157.0	0	
40	:30	5.0	2.00	.4	.260	.09	169.0	47.8	
41	:40	4.9	1.92	.3	.190	.09	164.0	30.3	50
42	:50	1.8	1.40	.3	.290	.09	151.0	0	
43	4:00	6.6	1.15	.4	.185	.08	165.0	45.0	
44	:10	6.3	2.05	.4	.185	.085	163.0	51.8	
45	:20	6.1	1.93	.3	.155	.075	153.0	5.4	
46	:30	5.9	2.00	.3	.150	.07	146.0	0	
47	:40	4.8	1.87	.3	.240	.08	137.0	9.9	
48	:50	5.0	1.92	.3	.240	.08	167.0	35.2	
49	5:00	6.2	2.05	.3	250	.07	169.0	49.8	
TOTAL –								1228.6	250.0
AVERAGE –		5.43	1.94	.5	.21	.104	166.2		

REMARKS –

TESTS OF DIFFERENT COALS IN A RESIDENCE HEATING BOILER (STEAM)

LOG SHEET

TEST No — 5

DATE — APRIL 22. 1907.

KIND OF COAL VIRGINIA-BLACK-BAND (SEMI-ANTHRACITE 4" LUMP)

No	TIME	PRESSURES					TEMP OF FEED WATER	WEIGHT FEED WATER	WEIGHT OF COAL
		STEAM			DRAFT				
		BOILER	SEPARATOR	EXHAUST	FLUE	FIRE-BOX			
1	4:40	3.6	2.00	.5	.120	.055	140.0	0	26
2	:50	3.9	2.00	.5	.120	.055	137.0	37.5	
3	5:00	3.0	1.90	.5	.100	.050	138.0	14.3	24
4	:10	3.0	2.20	.5	.130	.050	138.0	0	
5	:20	2.9	2.00	.5	.129	.054	139.0	55.6	
6	:30	4.3	2.15	.6	.154	.055	143.5	16.7	
7	:40	1.8	1.65	.4	.108	.053	147.0	37.4	
8	:50	1.6	1.50	.4	.080	.050	145.5	0	
9	6:00	1.0	.85	.3	.085	.050	144.5	0	50.0
10	:10	2.2	2.05	.6	.110	.050	143.5	0	
11	:20	4.7	2.15	.6	.115	.050	193.0	64.8	
12	:30	1.8	1.80	6	.075	.045	188.5	23.3	
13	:40	2.6	2.45	.7	.150	.057	187.0	56.3	
14	:50	4.6	2.00	.5	.119	.050	169.3	0	
15	7:00	4.7	1.93	.6	.120	.053	159.4	0	
16	:10	4.1	1.90	.5	.114	.052	197.5	30.0	
17	:20	3.8	1.90	.6	.107	.055	194.0	63.8	
18	:30	3.4	1.85	.5	.100	.053	163.0	4.4	
19	:40	2.3	1.75	.4	.109	.052	186.0	34.0	
20	:50	0.8	2.00	.4	.105	049	180.0	43.3	50.0
21	8:00	1.9	1.65	.4	.102	.040	161.0	0	
22	:10	3.4	1.93	.5	.114	.041	137.0	5.4	
23	:20	4.9	2.05	.6	.114	.040	177.5	72.1	
24	:30	5.0	2.00	.7	.102	.038	165.5	0	
25	40	5.1	2.02	.7	.100	.038	157.0	0	
26	:50	4.0	1.90	.6	.109	.038	169.0	25.4	
27	9:00	3.9	1.90	.5	.100	.040	175.0	40.0	
28	:10	3.1	1.88	.5	.110	.041	160.0	12.8	
29	:20	4.9	2.00	.5	.120	.042	141.0	7.9	
30	:30	4.3	1.95	.6	.144	.039	168.0	55.6	
31	:40	4.4	1.95	.4	.115	.041	168.0	20.5	
32	:50	2.1	1.65	.4	.102	.039	167.0	54.7	
33	10:00	0.5	.45	.2	.104	042	147.0	0	50.0
34	:10	0.4	1.00	.3	.101	045	143.0	0	
35	:20	0.5	1.08	.2	.096	.043	139.8	0	
36	:30	1.00	.65	.2	.079	.048	136.4	22.7	
37	:40	1.90	1.65	.3	.090	.042	145.0	26.5	
38	:50	2.10	2.00	.5	.098	.042	151.0	34.4	
39	11:00	4.90	2.05	.5	.107	.039	148.0	0	
40	:10	3.10	1.85	.4	.102	.043	152.0	61.9	
41	:20	4.10	1.95	.5	.097	.038	147.0	0	
42	:30	1.3	1.1	.3	.083	.043	147.5	49.1	
43	:40	1.5	1.4	.8	.091	.043	144.0	0	
44	:50	2.1	1.35	.4	.102	.039	167.0	10.8	
45	12:00	1.4	1.40	.3	.094	.040	146.0	62.0	
46	:10	1.6	1.45	.3	.080	.040	145.0	62.0	
TOTAL —								1105.2	200.0
AVERAGE —		2.9	1.75	.5	.107	.046	155.6		

REMARKS —

TESTS OF DIFFERENT COALS IN A RESIDENCE HEATING BOILER (STEAM)

LOG SHEET

TEST No - 6

DATE - MAY 8, 1907

KIND OF COAL - VIRGINIA - BLACK BAND (SEMI ANTHRACITE - 4" LUMP)

No	TIME	PRESSURES					TEMP. OF	WEIGHT	WEIGHT
		STEAM			DRAFT		FEED	FEED	OF
		BOILER	SEPARATOR	EXHAUST	FLUE	FIRE-BOX	WATER	WATER	COAL
1	12:00	1.1	.60	.30	.140	.088	123.0	0	26.0
2	:10	5.5	1.90	.60	.190	.088	124.0	5.9	
3	:20	3.0	1.85	.60	.130	.060	123.0	62.4	24.0
4	:30	4.1	1.85	.50	.120	.060	123.0	29.7	
5	:40	2.2	1.65	.50	.130	.062	125.0	55.4	
6	:50	4.2	2.00	.50	.130	.070	125.0	24.8	
7	1:00	4.3	1.95	.60	.130	.062	127.0	1.0	
8	:10	3.1	1.70	.60	.130	.060	118.0	13.9	50.0
9	:20	5.4	2.10	.65	.130	.060	216.0	23.1	
10	:30	4.3	1.80	.65	.130	.060	150.0	4.9	
11	:40	5.0	2.00	.55	.120	.054	136.0	83.9	
12	:50	5.6	2.00	.65	.110	.060	136.0	48.3	
13	2:00	5.0	1.90	.60	.115	.054	137.0	0	
14	:10	4.1	1.80	.60	.110	.054	138.0	0	
15	:20	4.6	2.00	.65	.110	.054	138.0	0	
16	:30	5.0	2.00	.65	.110	.054	137.0	0	
17	:40	4.2	1.95	.70	.110	.054	128.0	33.7	
18	:50	4.7	2.00	.65	.110	.058	130.0	19.8	
19	3:00	4.3	2.00	.65	.120	.058	160.0	41.2	
20	:10	4.3	2.00	.70	.110	.058	161.0	80.3	
21	:20	4.6	2.00	.65	.110	.058	154.0	1.0	
22	:30	2.6	1.85	.60	.110	.050	147.0	0	50.0
23	:40	3.1	2.05	.60	.100	.044	147.0	50.2	
24	:50	6.1	2.10	.60	.120	.048	143.0	45.4	
25	4:00	5.4	2.15	.70	.140	.046	145.0	0	
26	:10	4.2	2.00	.60	.150	.042	143.0	0	
27	:20	4.6	1.95	.65	.140	.048	166.0	31.3	
28	:30	4.5	2.10	.65	.130	.048	175.0	36.1	
29	:40	4.8	2.10	.75	.140	.048	175.0	56.5	
30	:50	4.6	2.00	.65	.140	.048	168.0	37.1	
31	5:00	3.3	1.90	.60	.140	.044	167.0	18.5	
32	:10	4.6	2.00	.68	.130	.044	160.0	15.7	
33	:20	4.7	2.00	.60	.140	.050	148.0	3.9	
34	:30	2.6	1.85	.55	.120	.048	170.0	16.6	50.0
35	:40	1.8	1.50	.45	.150	.040	176.0	35.1	
36	:50	2.3	2.00	.55	.130	.030	174.0	24.4	
37	6:00	3.9	2.00	.65	.120	.040	174.0	21.4	
38	:10	4.4	2.00	.70	.120	.032	168.0	17.5	
39	:20	4.9	2.00	.65	.130	.034	166.0	15.6	
40	:30	4.3	2.05	.70	130	.040	170.0	28.3	
41	:40	3.9	1.95	.65	130	.034	176.0	30.2	
42	:50	3.1	1.90	.65	130	.032	164.0	25.4	
43	7:00	3.8	2.00	.65	.140	.034	150.0	25.6	
44	:10	4.1	2.00	.60	.140	.032	164.0	4.9	
45	:20	2.8	1.80	.50	.140	.032	175.0	57.4	
46	:30	2.3	1.85	.50	.140	.032	170.0	11.3	
TOTAL -								1172.6	200.0
AVERAGE -		4.0	1.92	.61	.130	.051	152.0		
REMARKS -									

TESTS OF DIFFERENT COALS IN A RESIDENCE HEATING BOILER [STEAM]

LOG SHEET

TEST No.— 7

KIND OF COAL—ANTHRACITE

DATE— MAY 9, 1907

No	TIME	PRESSURES					TEMP. OF FEED WATER	WEIGHT FEED WATER	WEIGHT OF COAL
		STEAM			DRAFT				
		BOILER	SEPARATOR	EXHAUST	FLUE	FIRE-BOX			
1	1:30	.60	.25	.30	.190	.090	137.0	0	50.0
2	:40	1.00	.75	.40	.200	.098	139.0	61.1	
3	:50	.50	.25	.30	.170	.088	134.0	0	
4	2:00	.40	.25	.30	.180	.090	132.0	0	50.
5	10	1.00	.80	.30	.160	.105	133.0	0	50.0
6	20	5.50	2.15	.70	.240	.118	131.5	11.9	
7	30	6.10	2.20	.80	.215	.103	131.0	34.9	
8	40	5.90	2.20	.70	.190	.095	134.5	38.5	
9	50	5.50	2.10	.80	.180	.093	133.5	23.7	
10	3:00	5.20	2.05	.80	.170	.085	132.0	24.8	
11	10	4.90	2.05	1.00	.160	.101	161.0	25.5	
12	20	4.90	2.00	.90	.170	.083	163.0	28.3	
13	30	4.70	2.00	.60	.165	.083	163.5	29.3	
14	40	4.80	2.00	.60	.170	.085	162.0	27.4	
15	50	4.80	2.00	60	.170	.083	160.5	29.4	
16	4:00	4.80	2.00	.70	.170	.085	159.0	26.5	
17	10	4.70	2.00	.60	.170	.083	156.5	26.5	
18	20	5.00	2.05	.70	.160	.083	170.0	19.5	
19	30	4.90	2.00	.60	.170	.083	168.5	24.4	
20	40	4.90	2.00	.70	.160	.083	166.0	22.4	
21	50	5.00	2.05	.70	.180	.083	166.0	20.5	
22	5:00	5.00	2.05	.80	.170	.083	166.0	28.3	
23	:10	4.90	2.00	.70	.170	.085	166.0	33.2	
24	:20	5.00	2.00	.70	.180	.085	166.0	26.3	
25	:30	4.90	2.00	.70	.165	.085	158.5	20.2	
26	:40	4.30	2.00	.70	.170	.085	150.0	14.8	
27	:50	4.80	2.00	.70	.160	.065	149.0	32.0	
28	6:00	3.90	2.00	.70	.180	.083	187.0	23.3	
29	:10	1.00	.70	.30	.200	.095	185.0	31.1	75.0
30	:20	6.20	2.15	.70	.200	.103	182.0	27.2	
31	:30	4.20	2.05	.70	.180	.095	178.0	20.4	
32	:40	4.50	2.05	.70	.160	.085	176.0	22.4	
33	:50	4.60	2.00	.70	.160	.080	175.0	20.5	
34	7:00	4.50	2.10	.70	.160	.084	173.0	28.3	
35	:10	4.60	2.00	.60	.150	.082	171.0	33.2	
36	:20	4.80	2.00	.60	.150	.080	174.0	26.3	
37	:30	5.30	2.05	.60	.150	.080	177.5	20.2	
38	:40	4.80	2.00	.70	.150	.080	177.5	14.8	
39	:50	4.80	2.05	.60	.140	.078	175.0	32.0	
40	8:00	4.70	2.05	.60	.150	.080	174.0	23.3	
41	:10	4.60	2.05	.60	.150	.080	172.0	31.1	
42	:20	4.50	2.05	.60	.150	.080	170.0	27.2	
43	:30	4.50	1.95	.60	.150	.080	180.0	20.4	
44	:40	4.60	2.05	.60	.150	080	179.0	30.2	
45	:50	5.00	1.95	.60	.150	.080	177.8	32.1	
46	9:00	4.70	1.90	.60	.150	.082	175.0	27.2	
47	:10	5.50	1.85	.60	.160	.082	173.0	25.4	
48	:20	5.00	1.85	.60	.160	.082	171.0	28.3	
49	:30	2.10	1.75	.50	.160	.082	169.0	16.6	
TOTAL -								1210.0	225.0
AVERAGE-		4.33	1.83	.60	.170	.086	165.8		

REMARKS-

TESTS OF DIFFERENT COALS IN A RESIDENCE HEATING BOILER (STEAM)

LOG SHEET

TEST No – **8**

DATE – MAY 10, 1907.

KIND OF COAL – ANTHRACITE

No	TIME	PRESSURES					TEMP. OF	WEIGHT	WEIGHT
		STEAM			DRAFT		FEED	FEED	OF
		BOILER	SEPARATOR	EXHAUST	FLUE	FIRE-BOX	WATER	WATER	COAL
1	1:30	.7	.50	.30	.20	.108	158	0	100.0
2	:40	4.3	1.95	.60	.22	.112	161	17.7	
3	:50	6.7	2.20	.80	.20	.104	162	20.7	
4	2:00	5.5	2.10	.60	.19	.100	161	30.4	
5	2:10	5.2	2.10	.70	.17	.090	160	24.5	
6	:20	4.1	2.20	.70	.16	.084	158	24.4	
7	:30	4.7	2.00	.70	.16	.088	158	24.5	
8	:40	4.5	2.00	.70	.17	.090	156	26.5	
9	:50	4.5	2.00	.60	.16	.092	152	25.6	
10	3:00	4.5	2.00	.70	.17	.092	165	29.3	
11	:10	4.4	1.95	.70	.16	.085	164	25.4	
12	:20	4.3	2.00	.80	.17	.090	161	26.5	
13	:30	4.5	2.00	70	.17	.098	160	24.5	
14	:40	4.4	2.00	.80	.17	.090	158	24.4	
15	:50	4.4	2.00	.70	.19	.100	155	25.5	
16	4:00	4.5	2.00	.70	.17	.092	153	24.5	
17	:10	4.4	2.00	.70	.20	.110	152	25.6	
18	:20	2.6	1.80	.60	.20	.100	160	22.6	125.0
19	:30	0	0.00	.30	.21	.120	165	38.1	
20	:40	4.4	2.00	.60	.28	.140	163	35.2	
21	:50	6.5	2.15	.70	.22	.128	151	0	
22	5:00	6.5	2.00	.70	.21	.110	137	8.9	
23	:10	5.6	1.95	.70	21	.105	151	14.8	
24	:20	4.1	1.95	.70	.25	.130	154	26.5	
25	:30	7.1	2.20	.80	.24	.120	151	26.5	
26	:40	4.6	1.95	.65	.25	.135	151	27.5	
27	:50	4.9	2.00	.70	.26	.130	160	23.6	
28	6:00	4.8	2.00	.75	.16	.097	163	26.3	
29	:10	4.8	2.00	.60	.20	.100	161	26.5	
30	:20	4.7	2.00	.60	.27	.103	160	24.5	
31	:30	4.8	2.00	.70	.19	.090	161	40.2	
32	:40	4.7	2.00	.70	.19	.100	158	35.4	
33	:50	4.7	2.00	.70	.19	.100	154	26.5	
34	7:00	4.7	2.00	.75	.20	.100	167	29.3	
35	:10	4.7	2.00	.70	.19	.100	166	27.3	
36	:20	4.8	2.00	.70	.18	.100	163	27.3	
37	:30	4.8	2.00	.65	.19	.095	162	23.6	
38	:40	4.7	2.00	.65	.19	.095	160	27.5	
39	:50	4.7	2.00	.70	.23	.110	158	24.5	
40	8:00	4.7	2.00	.70	.20	.120	156	25.5	
41	:10	4.7	2.00	.70	.17	.090	152	21.7	
42	:20	4.7	2.00	.70	.19	.100	171	27.3	
43	:30	4.7	2.00	.70	.23	.110	170	22.4	
44	:40	4.7	2.00	.65	.20	.100	167	19.5	
45	:50	4.7	2.00	.65	.24	.120	161	14.7	
46	9:00	4.4	1.95	.70	.19	.092	152	9.8	
47	:10	4.2	1.95	.70	.20	.105	144	5.9	
48	:20	3.6	1.90	.50	.20	.105	167	31.3	
49	:30	1.8	1.40	.40	.20	.105	167	32.3	
TOTAL –								1173.0	225.0
AVERAGE –		4.5	1.96	.70	.20	.104	158.7		
REMARKS –									

ANALYSIS OF ASH			ANALYSIS OF REFUSE.								
PERCENT.	EARTHY MATTER PERCENT.	MOISTURE PERCENT.	CARBON PERCENT.	EARTHY MATTER PERCENT.	MOISTURE PERCENT.	WEIGHT OF WOOD POUNDS	BOILER PRESSURE AT START LBS. PER SQ. INCH.	BOILER PRESSURE AT END LBS. PER SQ. INCH.	WEIGHT OF WATER IN BOILER AT START POUNDS.	WEIGHT OF WATER IN BOILER AT END POUNDS.	MOISTURE IN COAL ON AIR DRYING PERCENT.
.14	70.43	.43	43.20	56.46	.36	8	3.2	8.1	302.8	285.3	2.5
.75	77.84	.41	36.33	63.34	.33	8	1.1	2.7	233.2	199.5	5.2
.57	74.99	.44	39.49	60.14	.37	10	0.5	4.1	244.8	225.3	5.0
.65	78.05	.30	41.37	58.26	.37	10	4.1	6.2	218.5	263.8	4.5
.71	43.74	.55	70.16	29.42	.42	10	3.6	1.6	241.1	249.6	2.6
3.39	41.14	.47	80.63	19.02	.35	10	1.1	2.3	216.7	225.5	1.8
3.97	50.83	.20	75.80	24.00	.24	14	0.6	2.1	219.3	252.5	2.2
7.19	42.41	.40	78.41	21.33	.26	20	0.7	1.8	233.8	193.3	1.8

OBSERVED DATA

Test No	Kind of Coal	Date	Duration of Test-Hours	Total Water Pounds	Total Coal Fired Pounds	Avg. Draft Ins of Water		Average Pressures			Avg Temp Deg Fahr.		Average Quality of Steam Percent Dry	Weight of Ash Pounds	Weight of Refuse Pounds	Proximate Analysis of Coal [Air Dry]				Analysis of Ash			Analysis of Refuse.			Weight of Wood Pounds	Boiler Pressure at Start Lbs. per Sq. Inch	Boiler Pressure at End Lbs per Sq. Inch.	Weight of Water in Boiler at Start Pounds	Weight of Water in Boiler at End Pounds.	Moisture in Coal on Air Drying Percent.
						In Flue.	Over Fire.	Boiler Lbs. Per Sq. In.	Separator Lbs Per Sq. In.	Exhaust Inches Mercury.	Feed Water.	Laboratory				B.T.U. Per Pound.	Moisture Percent.	Ash Percent.	Sulphur Percent.	Carbon Percent.	Earthy Matter Percent.	Moisture Percent.	Carbon Percent.	Earthy Matter Percent.	Moisture Percent						
1.	Herrin #2 Washed.	4-2,-'07.	8	1113.1	261	.073	.088	9.60	1.94	—	152.5	—	.9742	17.1	19.5	12771	3.26	8.66	1.36	29.14	70.43	.43	43.20	56.46	.36	8	3.2	81	302.8	285.3	2.5
2.	"	4-11,-'07.	7⅔	1559.0	375	.078	.121	3.86	1.72	1.0	177.4	88	.8816	26.3	26.65	12771	3.26	8.66	1.36	21.75	77.84	.41	36.33	63.34	.33	8	1.1	2.7	233.2	199.5	5.2
3.	"	4-12,-'07	8	1234.8	250	.130	.135	5.70	1.94	.7	159.2	78	.9572	11.0	23.4	12771	3.26	8.66	1.36	24.57	74.99	.44	39.49	60.14	.37	10	0.5	4.1	244.8	225.3	5.0
4.	Chicago & Herrin #2 Unwashed.	4-13,-'07.	8	1228.6	250	.210	.104	5.43	1.94	.5	166.2	80	.9695	13.3	28.2	12664	4.17	8.69	1.79	21.65	78.05	.30	41.37	58.26	.37	10	4.1	6.2	218.5	263.8	4.5
5	Virginia Black Band 4" Lump, Semi-Anthracite	4-22,-'07.	7½	1105.2	200	.107	.046	2.90	1.75	.5	155.6	85	.9129	11.1	24.2	13614	2.05	6.54	.69	55.71	43.74	.55	70.16	29.42	.42	10	3.6	1.6	241.1	249.6	2.6
6.	"	5-8,-'07.	7½	1172.6.	200	.130	.051	4.00	1.92	.6	152.0	.85	.9829	8.2	19.5	13758	2.33	5.29	—	58.39	41.14	.47	80.63	19.02	.35	10	1.1	2.3	216.7	225.5	1.8
7.	Anthracite Egg Size	5-9,-'07.	8	1210.0	225	.170	.086	4.33	1.83	.6	165.8	91	.9787	13.5	51.6	12794	2.18	10.45	.97	48.97	50.83	.20	75.80	24.00	.24	14	0.6	2.1	219.3	252.5	2.2
8.	"	5-10,-'07.	8	1173.0	225	.200	.104	4.50	1.96	.7	158.7	84	.9809	11.7	60.5	12794	2.18	10.45	.97	57.19	42.41	.40	78.41	21.33	.26	20	0.7	1.8	233.8	193.3	1.8

	A	B
Test No	Equivalent Evaporation from & at 212°	Total Coal, Correct-
1	1167.9	25
2	1468.7	36
3	1275.5	24
4	1214.1	24
5	1068.4	18
6	1222.7	18
7	1216.4	191
8	1261.5	18

CALCULATED DATA

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
TEST No	EQUIVALENT EVAPORATION FROM & AT 212°	TOTAL COAL CORRECTED, AS BURNED POUNDS	TOTAL DRY COAL BURNED POUNDS	TOTAL COMBUSTIBLE BURNED POUNDS	WATER EVAPORATED PER POUND OF COAL AS FIRED-POUNDS	WATER EVAPORATED PER POUND OF DRY COAL-POUNDS	WATER EVAPORATED PER POUND OF COMBUSTIBLE-POUNDS	TOTAL ASH CORRECTED	B.T.U. PER POUND OF COAL AS FIRED	B.T.U. PER POUND OF DRY COAL	B.T.U. PER POUND OF COMBUSTIBLE	POUNDS OF WATER PER HOUR FROM & AT 212°	WORKING CAPACITY OF BOILER SQ.FT. OF DIRECT RADIATION	PERCENT OF RATED CAPACITY	COAL BURNED PER HOUR PER 100 SQ.FT. OF RADIATION-POUNDS	BOILER EFFICIENCY (966 x G) ÷ K	COMBINED BOILER AND GRATE EFFICIENCY (966xF)÷J
1	1167.9	255.8	241.3	219.7	4.56	4.84	5.36	28.2	12451	13201	14499	146	565	70.5	3.77	35.7	32.2
2	1468.7	368.5	337.9	307.7	3.98	4.34	4.77	43.2	12107	13201	14499	191.7	740	92.5	5.51	31.1	31.7
3	1275.5	244.8	225.0	207.5	5.21	5.67	6.15	35.2	12132	13201	14499	159.4	615	77	3.51	40.9	41.5
4	1214.1	242.3	222.5	202.4	5.01	5.45	6.0	29.8	12094	13215	14532	151.7	586	73.2	3.48	39.8	39.8
5	1068.4	184.0	175.5	167.3	5.80	6.08	6.03	18.3	13260	13899	14893	142.3	550	68.8	2.92	39.1	42.2
6	1222.7	188.3	180.6	170.8	6.49	6.77	7.16	12.0	13510	14085	14893	163.0	630	78.5	3.01	46.4	46.4
7	1216.4	191.5	183.2	163.7	6.35	6.64	7.43	26.0	12513	13079	14643	152.0	587	73.4	2.83	49.0	49.0
8	1261.5	185.6	177.6	158.5	6.79	7.10	7.96	24.8	12564	13079	14643	157.7	608	76.2	2.77	52.5	52.4

Calculations:-

Sample calculations for test #1 will here be given in order to show the method used.

Weight of Water in Boiler at Start and at End: The specific volumn of water at the pressure at start or end multiplied by 4.31 gave the weight of water at 3-1/4" glass. From Chart 1 and the height of water in glass, the correction was found, which added to or subtracted from the amount above gave the total weight in boiler at start or finish, thus,

$$4.31 \times 59.58 = 256.8$$

Correction from chart $= +46.$

$$256.8 + 46 = 302.8 \text{ lbs.--wt. at start.}$$

A-Equivalent evaporation from and at 212 degrees:

$$= \frac{1113.1(1130.2 \quad 120.8) \quad 17.5(1130.2 \quad 191) \quad 285.3(204 \quad 191)}{966}$$

$= 1167.9$ lbs. water.

in which (a) 1113.1 = water fed to boiler.

(b) 1130.2 = heat of mixture above 32 degrees as evaporated.

(c) 120.8 = heat of liquid at feed water temperature.

(d) 17.5 = excess water in boiler at start over that at finish.

(e) 1130.2 = same as (b).

(f) 191.0 = heat of liquid at pressure at start of test.

(g) 285.3 = weight of water in boiler at end.

(h) 204.0 = heat of liquid at pressure at end of test.

(i) 191.0 = same as (f).

B-Total Coal, Corrected as Burned:

Weight of coal fired = 261 lbs.

Equivalent coal in wood fired = 8 x 0.4 = 3.2

Total coal fired = 261 + 3.2 = 264.2

Unburned coal assumed to be remaining in refuse

0.432 x 19.5 = 8.4 (where 0.43 carbon in refuse.)

Total coal burned = 264.2 − 8.4 = 255.8

C-Total Dry Coal Burned:

Moisture in coal on air drying = 2.5%

Moisture in coal at 105 deg.C. = 3.26%

Total moisture in coal as fired

= 2.5 + 3.26(1.00 − .025) = 5.68%

Total dry coal = (1.00 − .0568)B = 241.3 lbs.

D-Total Combustible:

Moisture in coal as fired = 5.68%

Ash in coal as fired = 8.44%

Combustible in air-dry coal

100 − (5.68 + 8.44) = 85.88%

Total combustible = .8588 x 255.8 = 219.7 lbs.

H-Total Ash (Corrected):

Ash as weighed = 17.1 Lbs.

Ash in refuse = (wt. of refuse – carbon in refuse)

= 19.5 - 8.4 = 11.1

Total ash = 17.1 + 11.1 = 28.2 lbs.

I-B.T.U.Per Pound of Coal as Fired:

B.T.U.of air-dry coal by calorimeter = 12771

Moisture on air drying = 2.5%

B.T.U.per pound as fired = 0.975 x 12771 = 12,451

J-B.T.U.Per Pound of Dry Coal:

Moisture in air-dry coal = 3.26%

B.T.U. per pound air dry = $\frac{12771}{.9674}$ = 13,201

K-B.T.U.Per Pound of Combustible:

Moisture in air dry coal = 3.26%

Ash in air dry coal = 8.66%

Combustible in air dry coal = 1. (.0326 + .0866) = .8808

B.T.U.per pound of combustible = $\frac{12771}{.8808}$ = 14,499

M-Working Capacity of Boiler:

In determining the working capacity of the boiler it was assumed that one square foot of direct radiation requires 250 B.T.U. per hour. This is a value given by different authorities.

$$\text{Capacity} = \frac{146 \times 966}{250} = 566 \text{ Sq.Ft. Direct Radiation.}$$

in which 146 = Evaporation per hour from and at 212 degrees.

Conclusions:

In these experiments four differents coals were tested, namely,

(a) Herrin No.2 Wash Coal (tests 1, 2, and 3).

(b) Chicago & Herrin No.2 unwashed (test 4).

(c) Virginia Black Band (Semi-anthracite, 4" lump, tests 5 and 6)

(d) Anthracite (Egg size, tests 7 and 8).

Coals (a) and (b) are from the same locality, Herrin, Ill., but not from the same mine, having been mined about one mile apart.

It was the intention at the beginning to run two tests on each coal under the same conditions. This was not done except with the last two coals.

In test 1 the coal was fired in small quantities at frequent intervals. This was a very unsatisfactory method for it required almost constant attention, which could not be given to a house boiler in actual service. Furthermore, it was impossible to keep the pressure even fairly constant by regulating the draft by hand as was done in this test. After test 1 it was

decided to fire the coal in fifty-pound quantities and to let the automatic regulator operate the drafts. This method was much better than the first one as the fire required but little attention and the automatic regulator kept the pressure almost constant.

In the second test an orifice was used which caused the boiler to work at 92.5% of its rated capacity instead of about 75% as was used in the other tests.

In the third test the same method was used as in the second, though a smaller orifice was used to make the boiler work at 75% of its capacity.

From these three tests it was found that at full capacity the boiler required 57% more coal per pound of water than at three-quarters capacity, or when carrying 600 square feet of direct radiation. A comparison of 1 and 3 shows that the frequent firing required about 7% more coal than the firing of large quantities less frequently. The remaining tests were run under the same conditions as No.3. Hence the results of No.3 were used in comparison with the results of the subsequent tests.

The basis of comparison was taken as "Pounds of air dry coal burned per hour per hundred square feet of direct radiation". These values appear under O in the calculated data on page 36.

Only one test was run on the Chicago & Herrin unwashed coal, as the supply was exhausted before a second test could be run. From the results of 3 and 4, which were 3.51 pounds and 3.48 pounds respectively, it appears that the unwashed was more economical. We cannot conclude this from one test on each coal, as duplicate tests might show a difference in favor of the unwashed coal. We can conclude, however, that the economy of one over the other is small.

The results of the two tests on the Virginia Black Band coal agree very closely, 2.92 pounds and 3.01 pounds per hr. per hundred sq.ft. of radiation, which is about 14% less than the amount required with the Herrin coal.

The Anthracite was fired in about one hundred pound quantities, as it would not burn to advatage when less amounts were fired. It required less attention and burned more uniformly than any of the other coals. It burned longer without firing than did the other coals, but we cannot give it credit for this as the other coals were fired in smaller quantities. The economy was higher than in any of the other tests, being 2.83 pounds and 2.77 pounds, or requiring 6.5% less coal than in the use of the Virginia Black Band.

To sum up the results on the four coals, take the pounds of Herrin washed coal per hour per hundred square feet

of radiation as unity, the relative amounts of each coal required for equal surface will be;

Herrin No.2 washed	1.00
Chicago & Herrin No.2 unwashed	.99
Virginia Black Band	.85
Anthracite	.80

These results show to a fair degree of accuracy, the comparative value of the different coals. Better results would be obtained if a few improvements were made in the apparatus and method, namely:

(a) The feed water thermometer 5 Fig.8 should be placed farther from the boiler, say at 6 Fig.8, and the pipe between it and the boiler heavily lagged. Then the thermometer would not be affected by the heat of the boiler and be made to read higher than the actual feed water temperature, as was possibly the case in these tests.

(b) An ultimate analysis of the coal should be obtained, for with the proximate analysis the amount of unburned coal remaining in the refuse cannot be accurately determined.

(c) In order to prevent radiation losses from the boiler, it should be covered with plastic asbestos cement 1-1/4" thick. This would require 200 pounds of the material.

A great deal of trouble was experienced with the flue

at the beginning. In the first five tests the chimney in the wall of the building was used. According to rules given by the American Radiator Company, this boiler should have, in a chimney of this height, about 100 square inches area. This chimney was supposed to be 8" x 16", or 128 sq.in. area, but at the thimble it measures only 6"x 15-1/2", or 93 sq.in. area. This would possibly have worked had not the smoke pipe been so long and full of elbows and cracks. As it was, the furnace would not draw. A small steam jet was placed in the chimney, and sufficient draft was then obtained. The moisture from this steam jet soon soaked the bricks and mortar of the chimney to such an extent that its use had to be discontinued. A galvanized iron extension 9 inches in diameter and 6 feet high was placed on top of the chimney, but this helped very little. Finally a 14 inch galvanized iron stack 40 feet high was erected as is shown in Fig.8. This arrangement furnished sufficient draft for the furnace.

UNIVERSITY OF ILLINOIS-URBANA
3 0112 086825269